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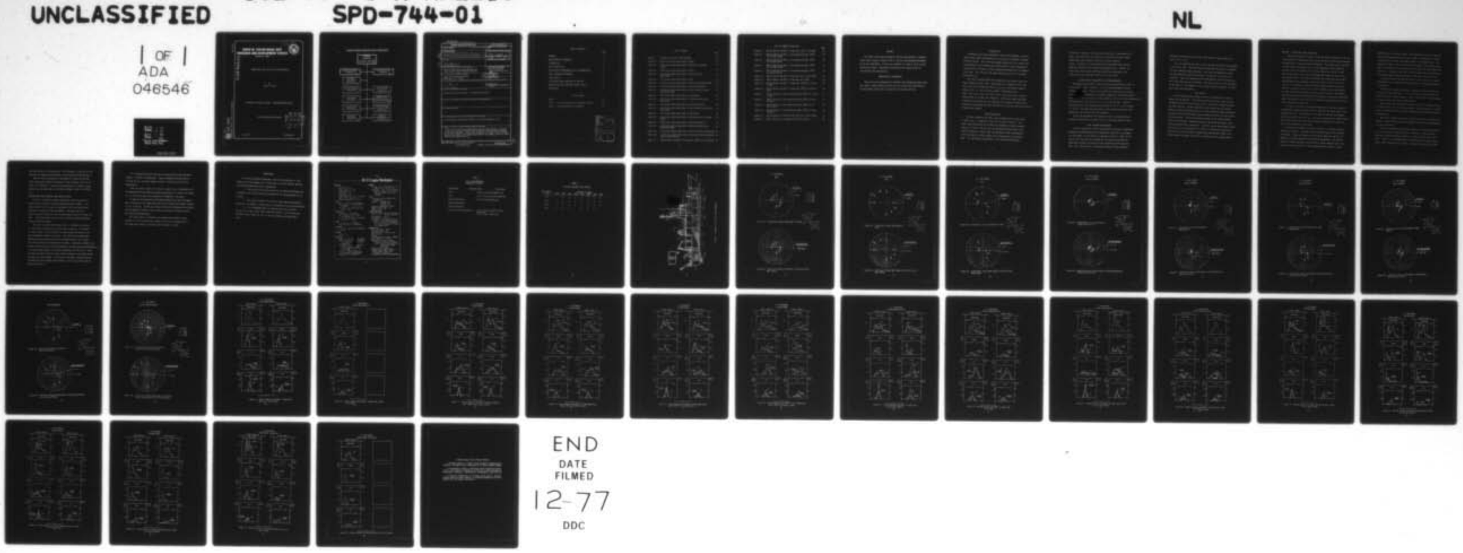

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SEAKEEPING TRIALS OF THE R/V CAPE HENLOPEN

by

James A. Kallio

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Ship Performance Department

July 1977

SPD-744-01

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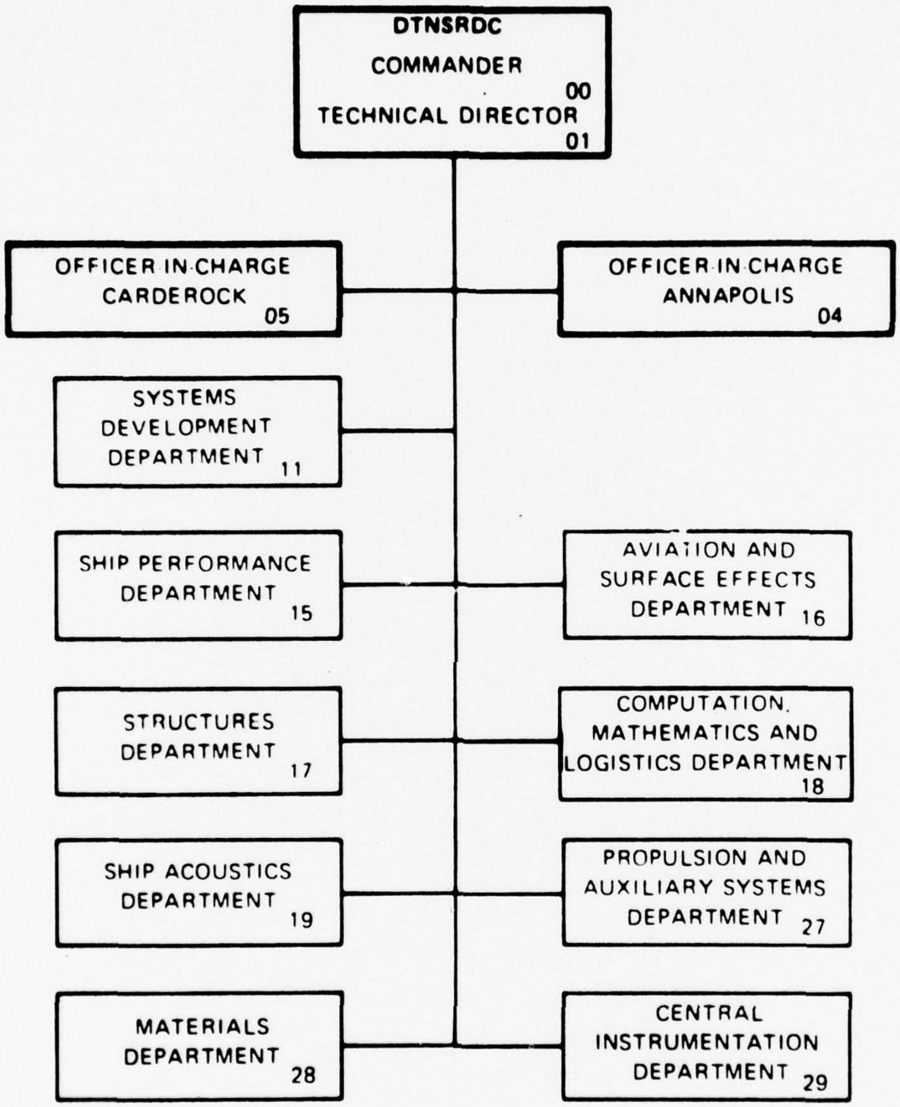

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Full scale trials were conducted on the R/V Cape Henlopen, a research vessel with an overall length of 120 ft (36.6 m) and maximum displacement of 165 tons (168 MTSW). Trials were conducted in a State 3 sea at various headings and speeds. Measurements were made of the seaway as well as craft motions and accelerations.

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ABSTRACT

Full scale trials were conducted on the R/V Cape Henlopen, a research vessel with an overall length of 120 ft. (36.6 m) and maximum displacement of 165 tons (168 MTSW). Trials were conducted in a State 3 sea at various headings and speeds. Measurements were made of the seaway as well as craft motions and accelerations.

ADMINISTRATIVE INFORMATION

These trials were conducted for the Naval Ship Engineering Center under work request numbers 65840 and 66181, David W. Taylor Naval Ship Research and Development Center work unit numbers 1572-135 and 1572-138.

INTRODUCTION

Seakeeping trials were conducted on the R/V Cape Henlopen, a new research vessel owned and operated by the University of Delaware's College of Marine Studies. This craft was designed specifically for coastal zone and continental shelf research with prime missions in the oceanographic research areas of trawling, coring, dredging and deploying of instrumentation arrays. The craft has high speed capability as well as low speed maneuverability.

The trials reported herein were conducted in the Atlantic Ocean off Lewes, Delaware in April 1976. Experiments were conducted in head, bow, beam, stern and following Sea State 3 [significant wave height approximately 3.6 ft. (1.1 m)] at various speeds. Measurements were made of the seaway, the craft pitch and roll and vertical and horizontal accelerations at various craft locations. Significant double amplitudes of motions and accelerations are reported at all speeds and headings and response amplitude operators were obtained at all but the stern quartering and following sea headings.

CRAFT DESCRIPTION

Principal dimensions and other craft characteristics are presented in Table 1 and a schematic of the craft is shown in Figure 1. The craft, newly acquired by the University of Delaware's College of Marine Studies is a 120 ft. (36.6 m), 65 ton (168 MTSW) research vessel specifically designed for coastal zone and continental shelf investigations involving trawling, coring, dredging and instrumentation array deployment. The craft design incorporates a hard chine high performance hull which is unique in that the planing condition is approached at 21 knots. While the craft is capable of an 18 to 20 knot cruise speed, controllable pitch propellers provide low speed maneuverability. A variety of on board hydraulically operated frames provide handling capabilities for numerous oceanographic tasks. Modular research vans, which may be outfitted on shore and used both on the craft and on shore, add great flexibility to the craft.

DESCRIPTION OF MEASUREMENTS AND INSTRUMENTATION

Measurements were made of craft motions and accelerations as well as of the seaway. Table 2 presents a list of these measurements and the transducer locations. Pitch and roll motion and surge, sway and vertical accelerations were measured by instruments mounted on a stablized platform located 3.6 ft. (1.1 m) to port of the centerline, 48.3 ft. (14.7m) forward of the aft perpendicular (AP) and 11.6 ft. (3.5 m) above the keel. Vertical acceleration was also measured near the stern at 17.7 ft. (5.4 m) forward of the AP. The seaway was measured by a free floating buoy which telemetered wave data to the craft for recording.

During the experiments the transducer signals were amplified and recorded in analog form on paper strip chart and analog magnetic tape.

TRIAL PROGRAM AND PROCEDURE

The trial program for the R/V Cape Henlopen consisted of experiments conducted at eight headings to the predominant direction of the seaway at four speeds in a Sea State 3 as detailed in Table 3. About 15 minutes of real time data was collected for the head, bow and beam sea conditions and about 25 minutes for the quartering and following sea runs. The trials were run in the Atlantic Ocean off Cape Henlopen, Delaware, about 40 miles (64 m) from shore where the water depth was at least 120 ft. (37 m).

Prior to beginning each day's trials, the wave height buoy was deployed in the trials area. Wind direction was established and used as a reference for the predominant seaway direction. The craft was steadied on course and speed whereupon data collection was initiated for a particular run condition. Course and speed were controlled manually from the pilot house until data collection was terminated. The length of each run was determined by the amount of time needed to collect about 200 wave encounters for each particular speed and heading.

TRIAL RESULTS

The data obtained during these trials was analyzed both in the frequency and time domains. This analysis yields mean values, power spectra, histograms and Fourier transforms as well as statistical information about the time histories. The data presented in this report are the response spectra, response amplitude operators and the significant double amplitudes (average of the one-third highest peak to peak excursions) of craft motions and accelerations. Significant absolute motions at the stable platform location (called heave, surge and sway) were calculated from heave, surge and sway accelerations, respectively. The first set of data presents significant motions and accelerations as a function of heading and speed while the second set of data presents response amplitude operators (RAO's) and motion spectra for heave, pitch and roll together with the seaway spectra.

MOTIONS - SIGNIFICANT DOUBLE AMPLITUDES

Figures 2a through 10a present significant double amplitudes of motions and accelerations (heave, surge and sway motions were calculated from measured accelerations) at various speeds and headings. The heading angles indicated on these figures in degrees, refer to the predominant seaway direction relative to the craft moving in a direction parallel to the 0^0 to 180^0 line on the figure, thus a 90^0 heading means the seaway was coming from the starboard beam. It should be noted that the significant wave heights recorded during the experiments varied from 3.22 ft (.98 m) to 3.97 ft. (1.21 m), a difference of about 23 percent, therefore data are also presented in Figures 2b through 10b in terms of motion per unit wave height in order to obviate misleading conclusions about the craft's performance. These motions per unit wave height were obtained by dividing the significant double amplitudes of the motion by the significant wave height for the particular experimental condition.

In Figures 2a and 2b, which present heave motion, the data indicated no appreciable speed or heading effect on heave for the speed range in bow through head seas. The difference in the data for the beam sea headings would indicate that the roll axis is not on the centerline but rather toward the leeward side of the craft since the heave transducer was slightly to port of the centerline of the craft.

Pitch motion, presented in Figures 3a and 3b, is affected little by speed at any heading. The highest pitch was experienced at the 150^0 bow sea heading. Figure 3b indicates that pitch was about the same for all speeds at the stern quartering and following sea headings. Roll motion (Figure 4a and 4b) decreases significantly as speed increases from 2.5 to 10 knots in beam seas while in bow and quartering seas there is little speed effect on roll above 5 knots. The difference in the roll data for port and starboard beam sea at a given speed is explained by the shape (distribution of energy) of the wave spectra for comparable runs. For example, in Figure 11 and 12, and 19 and 20, there is more seaway energy near roll resonance for the experiment during which the craft experienced larger roll. Generally, the craft roll motion decreases significantly as the heading changes from beam to head or from beam to following seas.

Surge acceleration (Figures 5a and 5b) is very small at all speeds and headings and is generally about the same for all speeds and headings investigated.

Surge motion (Figures 6a and 6b) is generally small and unaffected by speed in head and bow seas. In stern quartering and following seas surge increases as speed increases. Surge is much larger in stern quartering than in head, bow, beam or following seas.

Sway acceleration, presented in Figures 7a and 7b is affected little by speed for the 2.5 to 10 knot speed range. Sway acceleration is largest at the 120 degree bow seas and beam sea headings and smallest in head and following seas.

Sway motion (Figures 8a and 8b) is generally small at all speeds and headings. Heading effect on sway displacement follows the trend observed for sway acceleration.

Vertical acceleration at the stable platform, called heave acceleration, is presented in Figures 9 and 9a. Generally, in beam, bow and head seas, heave acceleration increases as speed increases from 5 to 10 knots. There is little speed effect in following seas on heave acceleration. Heave acceleration is largest in bow and stern quartering (300^o)

seas and smallest in following seas. The difference in the data for the two beam sea headings was explained in the discussion on heave motion.

Vertical stern acceleration is presented in Figures 10a and 10b. Stern acceleration generally increases as speed increases from 5 to 10 knots in all headings. Vertical stern acceleration is largest in head and bow seas and decreases as the heading changes to beam or following sea.

RESPONSE AMPLITUDE OPERATORS, AND ENERGY SPECTRA

Figures 11 through 26 present sea spectra, pitch, heave and roll motion spectra and motion response amplitude operators (RAO's). The energy spectra for the seaway, as measured by the free floating buoy, have been corrected for speed and heading. The spectra for the motions were then divided by the corrected seaway spectra to produce the RAO's. Indicated on each figure are the significant double amplitudes of wave height and motions.

The reader is again reminded that there is considerable variation in significant wave height for a given speed or heading. Also evident in these figures is the difference in seaway energy distribution from one experimental condition to another. This should be considered when drawing conclusions about the craft's performance and for this reason, the motion spectra are presented with the RAO's. Generally, the RAO's and response spectra peak near the same frequency, and the seaway contained energy in a broad enough range to elicit motion responses from the craft. There are some cases where division of the response spectra by the seaway spectra resulted in a very high RAO. In such cases, the RAO is truncated because the magnitude of the numbers being divided is not of the proper order for these calculations.

It is interesting to note that the sea spectra usually have two peaks, around ω = 0.8 and 1.4 radians/sec. These correspond to wave periods of 7.85 and 4.5 sec. with wave lengths of 316 ft. (96 m) and 103 ft. (31 m) respectively.

Since the craft's natural roll period is about 5 sec., considerable roll was experienced in bow, beam and quartering headings at 2.5 knots (see Figures 11, 13, 18, and 21) due to the inherently low damping at low speed.

In head, bow and quartering (330 degree heading) seas the craft heaved more in response to the longer waves than to the shorter wave lengths (Figures 13, 16, 17 and 23). In beam seas (Figure 19) and the 300 degree stern quartering sea headings (Figures 21 and 22) the craft heaved in response to both wave lengths mentioned above.

The craft pitches in response to the shorter wave lengths in head (Figures 17 and 18) and bow seas (Figures 13 to 16) and responds most to the longer wave lengths in quartering seas (Figures 21 to 24).

CONCLUSIONS

Full scale experiments conducted on the R/V Cape Henlopen in a Sea State 3 at various speeds up to 10 knots and at various headings indicate the following about the craft's performance:

1. The craft's motions and acceleration in head and following seas at speeds up to 10 knots are quite satisfactory for the performance of its mission.

2. The craft's extensive roll motion in bow, beam and quartering headings at low speeds is largely due to low damping and can be uncomfortable.

3. It is recommended that roll damping devices be installed on the craft to help reduce these large roll motions. Such a device may be either active stabilizer fins or the less expensive paravane stabilizer.

TABLE I

R/V Cape Henlopen

Physical

- Year built — 1975
- Length overall — 120'
- Length at waterline — 109'
- Breadth, MLD — 23'9"
- Depth, MLD — 10'4"
- Draft (loaded) — 9'9"
- Height to masthead — 48', plus antennas
- Hull material — Aluminum
- Maximum displacement — 165 tons

Power

- Engines — two 16V-149 TI GM diesels
- Shaft horsepower — 2,800 total SHP at 1,900 RPM
- Generators — two 75 KW 208/120 VAC, 3 phase, 60 Hz

Performance

- Speed range — 0 to 21 knots
- Speed, cruising — 18 to 21 knots, depending on load
- Range — 900 miles at top cruising speed; 4,000 miles at 12 knots

Tanks

- Fuel oil capacity — 6,600 gallons
- Fresh water capacity — 1,000 gallons

Evaporator

- Maxim HJ10A (Rated capacity: 480 gallons per day)

Quarters

- Crew — 6
- Scientists — 12

Electronics

- Radars (2) — Decca RM[illegible] Decca RM929
- Radios (2) CAI CA-35[illegible] SSB Transceiver; RF442 VHF [illegible]eiver with guard receiver
- Depth sounders (3) — [illegible] FPG-512H (2,000 fm range); [illegible] F861A (130 fm range); Benmar DI-18 (60 fm range)
- Lorans (2) — Teledyne TDL-601 with remote readout; Simrad LCA-204
- Automatic Pilot — Sperry Mark 37

Winches

- Trawling — Marco 1500 double-drum with 3,000 m. of ½" cable per drum
- Hydrographic — Marco W1928 single-drum with either 4,000 m. of 3/16" rope or 2,000 m. of conductor cable (interchangeable)

Crane

- Husky Mariner, Marine Hydraulic Crane Model M125
- Capacities — 12,500 lbs. at 8'; 6,400 lbs. at 16'; 4,550 lbs. at 22'
- Maximum horizontal reach — 22'8½"
- Maximum vertical reach — 28'
- Degree of swing — 30°

Scientific Work Space

- Open Deck Space — 840 sq. ft. (without van); 712 sq. ft. (with van)
- Wet Laboratory — 130 sq. ft.
- Dry Laboratory — 130 sq. ft.
- Refrigeration — Foster HLR-20-20-R combination freezer/refrigerator (cubic-foot capacity — freezer, 20.1; refrigerator, 19.5; shelf area (square feet) — freezer, 15.5; refrigerator, 20.1)

Laboratory Van

- Exterior Dimensions — 8x8x16'
- Rear double doors — 4x6'
- Doors open 270° and hook to van sides
- Aluminum body
- Insulated
- Self-contained heat and cooling — 5,000 BTU
- Power transformer — 10 KVA
- Modular furniture units — 4' long
  - Attached to uni-struts on 2' centers
  - Includes: sink unit, desk unit, electronic instrument rack, shelves, cabinets, etc.
- Van base weight — 3800 lbs.
- Modular furniture weight — 600 lbs.
- Available weight for your scientific equipment — 3100 lbs.
- Weather-tight seal to ship or building doorway

TABLE 2

LIST OF MEASUREMENTS
TRANSDUCER LOCATION

Wave Height	Waverider Buoy - open ocean	
Pitch		48.3 ft (14.7m) forward of AP
Roll		3.6 ft (1.1m) port of Centerline
Heave Acceleration		11.6 ft (3.5m) above keel
Surge Acceleration		
Sway Acceleration		
Vertical Stern Acceleration		17.7 ft (5.4m) forward of AP on centerline 11.6 ft (3.5m) above keel

TABLE 3

R/V CAPE HENLOPEN TRIAL MATRIX

SHIP SPEED KTS	HEADING TO SEAWAY 90°	120°	150°	180°	270°	300°	330°	360°
2.5		X	X	X	X	X	X	X
5.0	X	X	X	X	X	X	X	X
8.0	X	X	X	X	X	X	X	X
10.0	X	X	X		X	X	X	

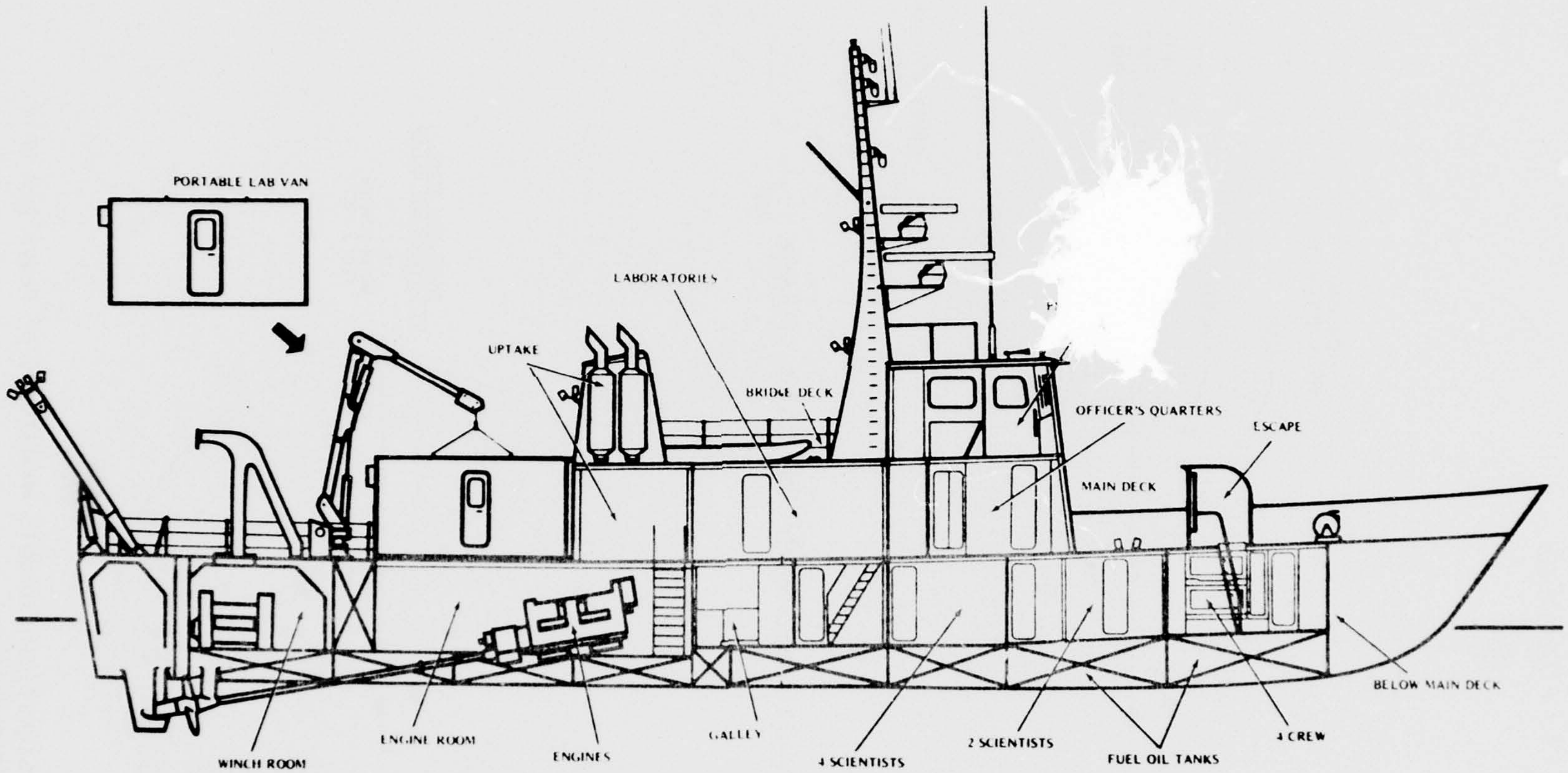


Figure 1 - Schematic of the R/V CAPE HENLOPEN

R / V CAPE HENLOPEN

HEAVE

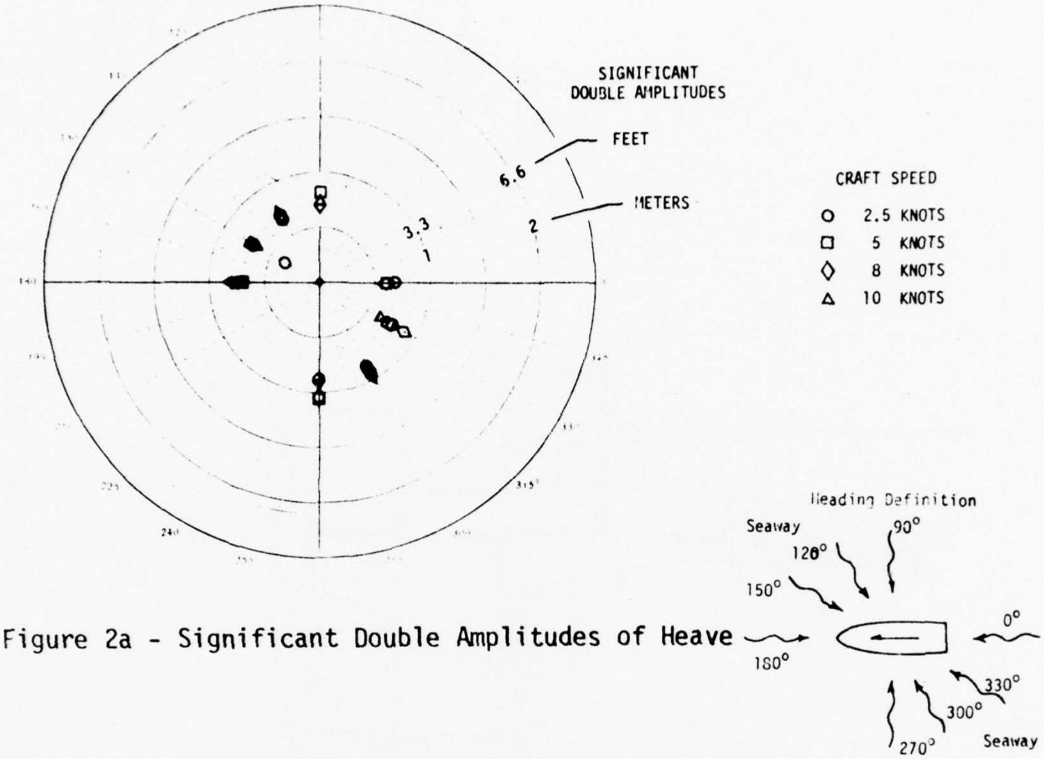


Figure 2a - Significant Double Amplitudes of Heave

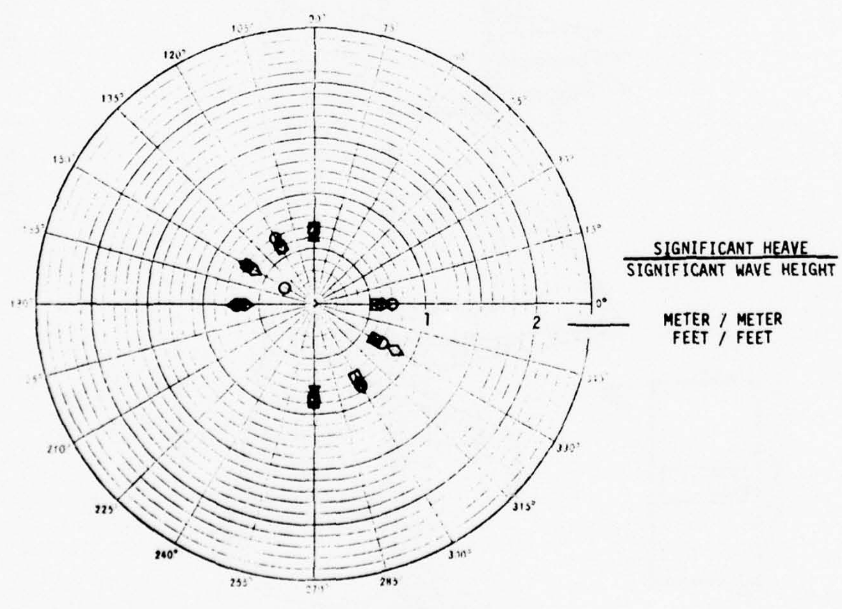
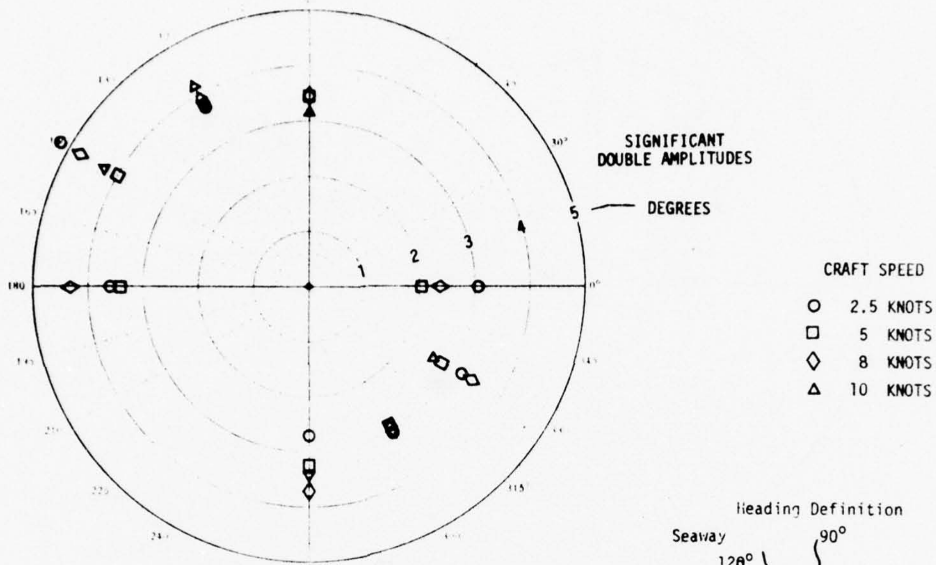


Figure 2b - Significant Double Amplitudes of Heave per Unit Wave Height

R / V CAPE HENLOPEN

PITCH



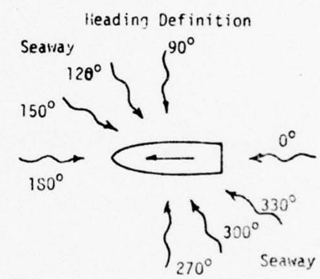


Figure 3a - Significant Double Amplitudes of Pitch

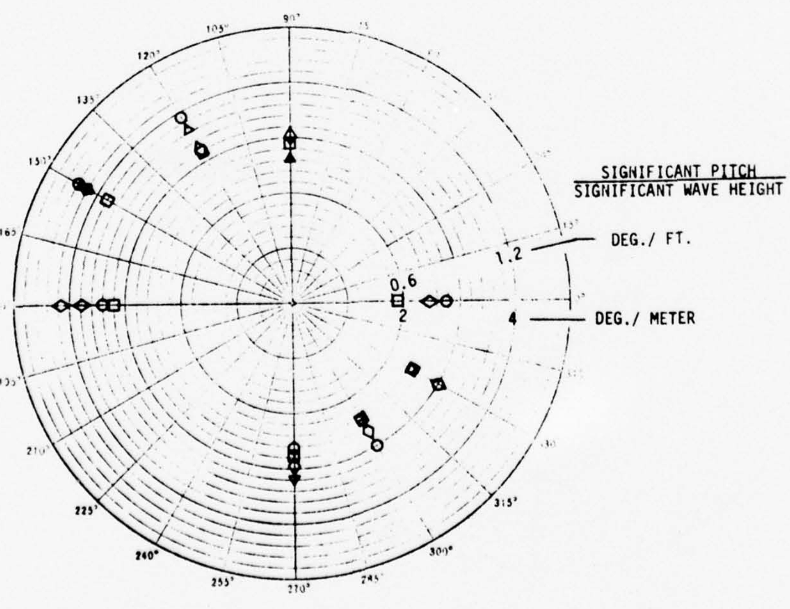
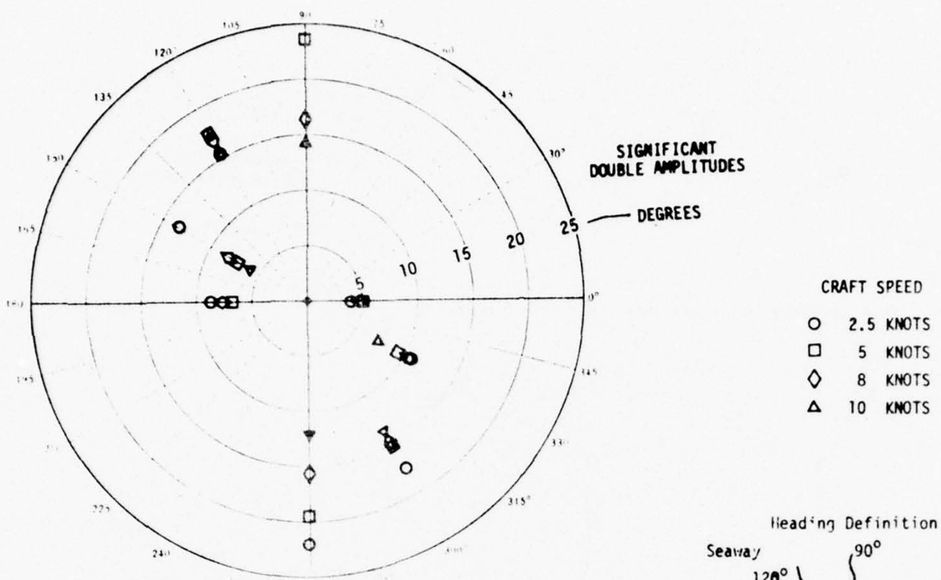


Figure 3b - Significant Double Amplitudes of Pitch Per Unit Wave Height

R / V CAPE HENLOPEN

ROLL



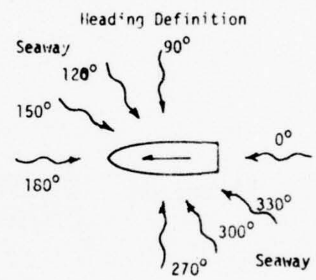


Figure 4a - Significant Double Amplitudes of Roll

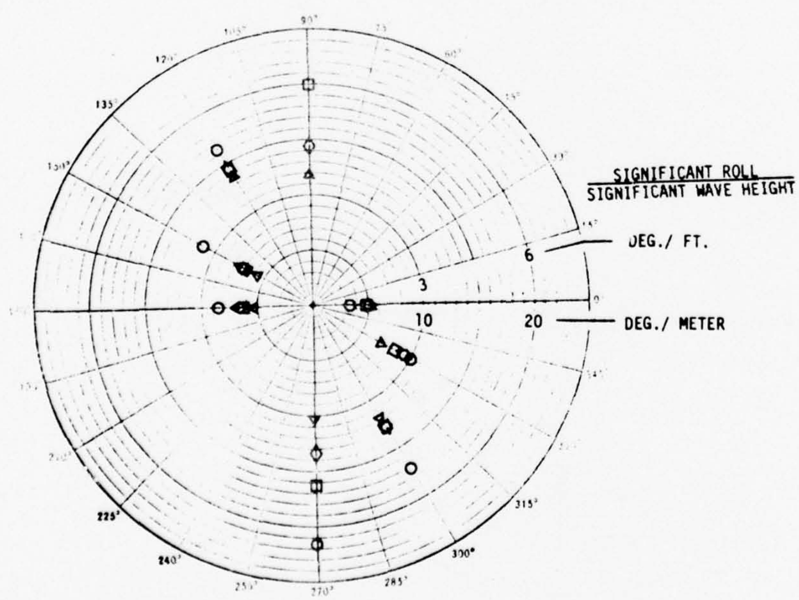


Figure 4b - Significant Double Amplitudes of Roll Per Unit Wave Height

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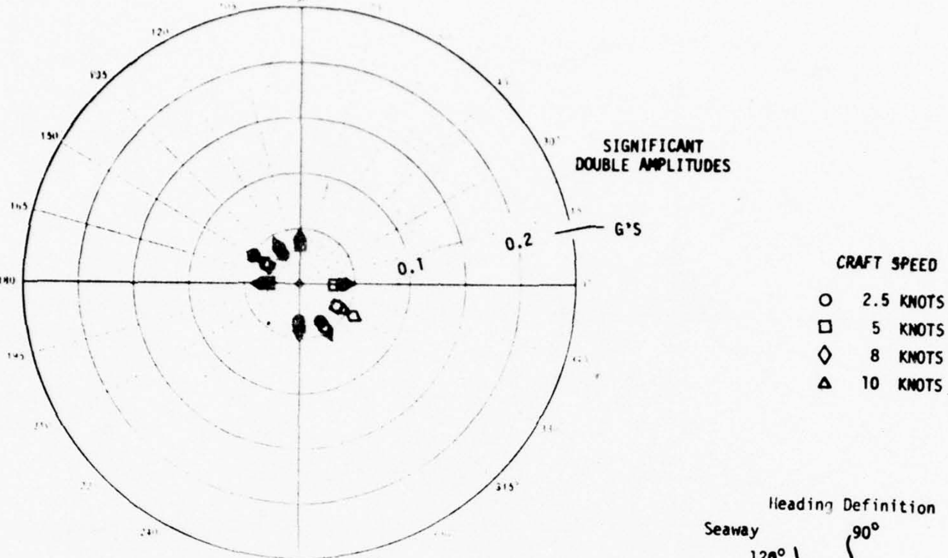
SURGE ACCELERATION



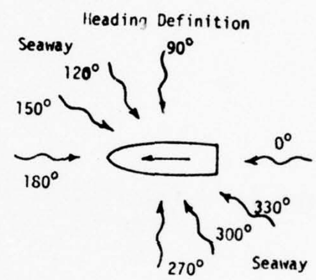


Figure 5a - Significant Double Amplitudes of Surge Acceleration

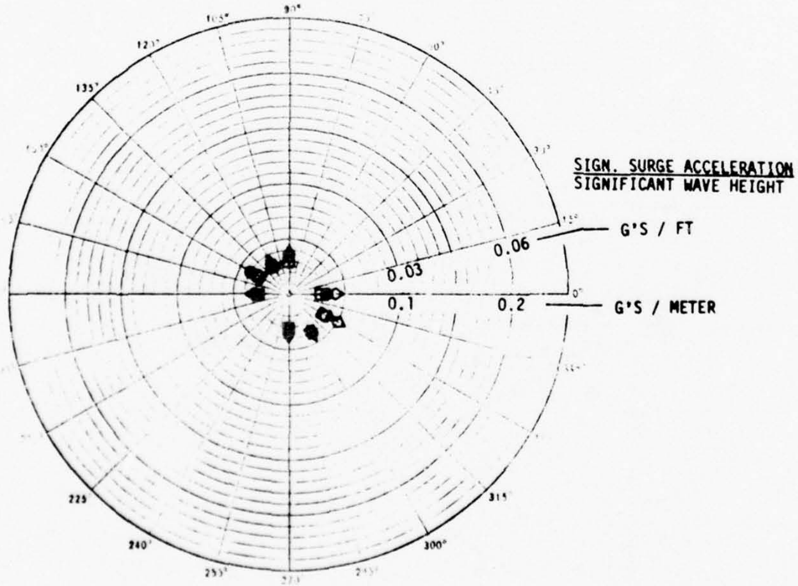
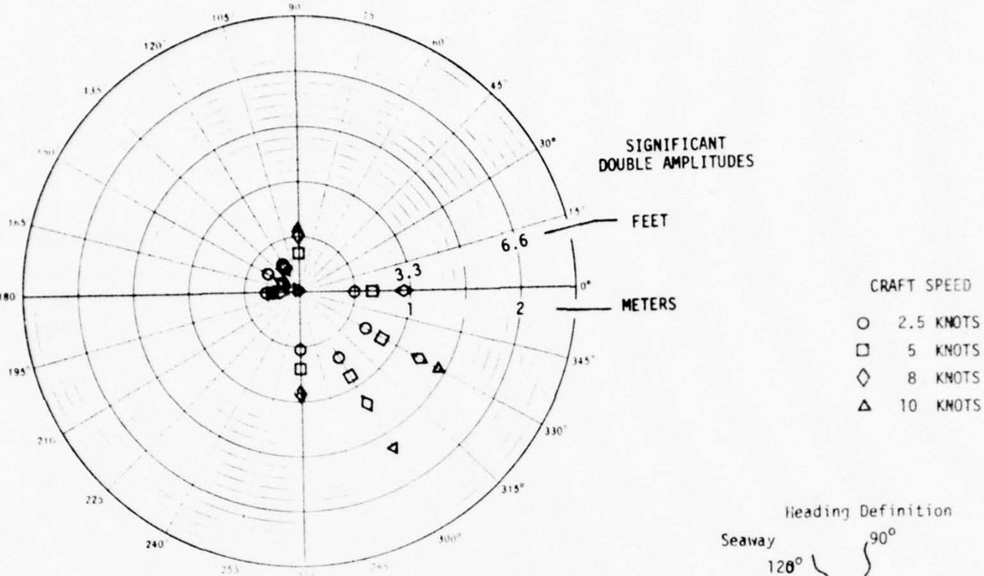


Figure 5b - Significant Double Amplitudes of Surge Acceleration Per Unit Wave Height

R / V CAPE HENLOPEN

SURGE DISPLACEMENT



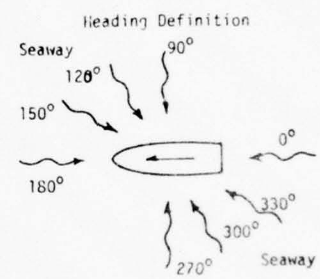


Figure 6a - Significant Double Amplitudes of Surge Motion

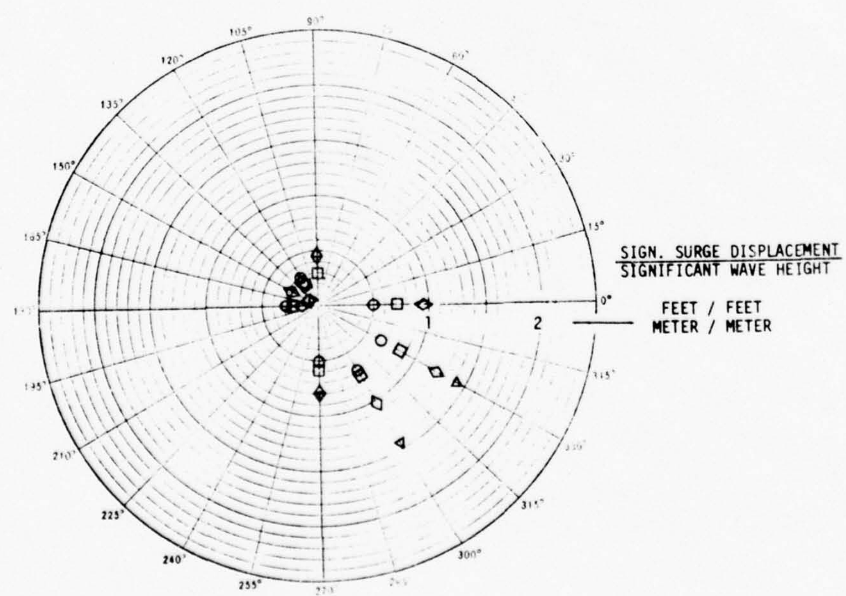


Figure 6b - Significant Double Amplitudes of Surge Motion Per Unit Wave Height

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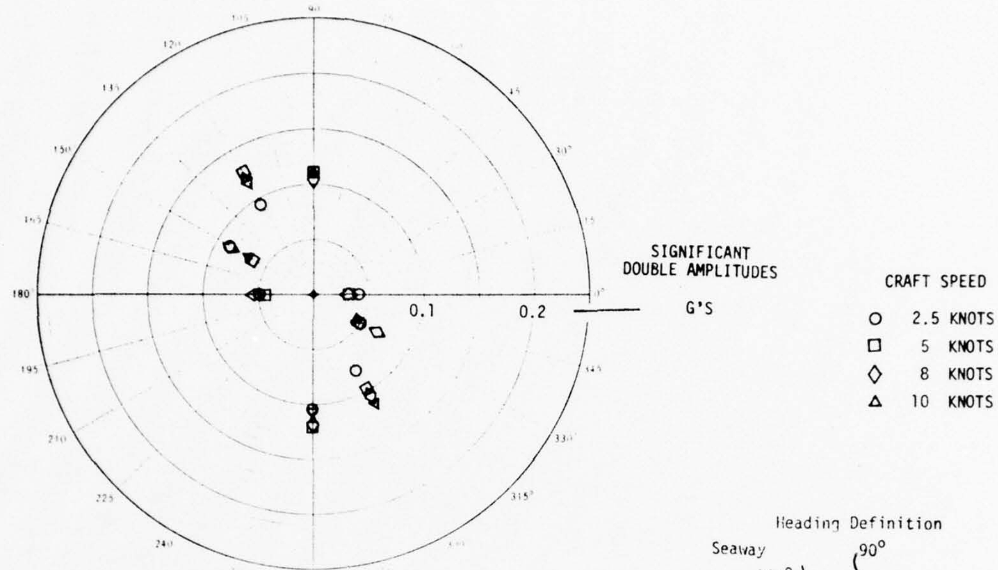
SWAY ACCELERATION



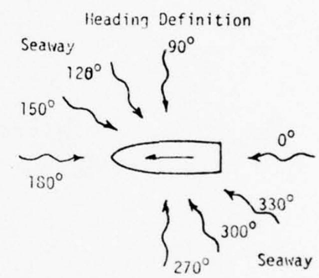


Figure 7a - Significant Double Amplitudes of Sway Acceleration

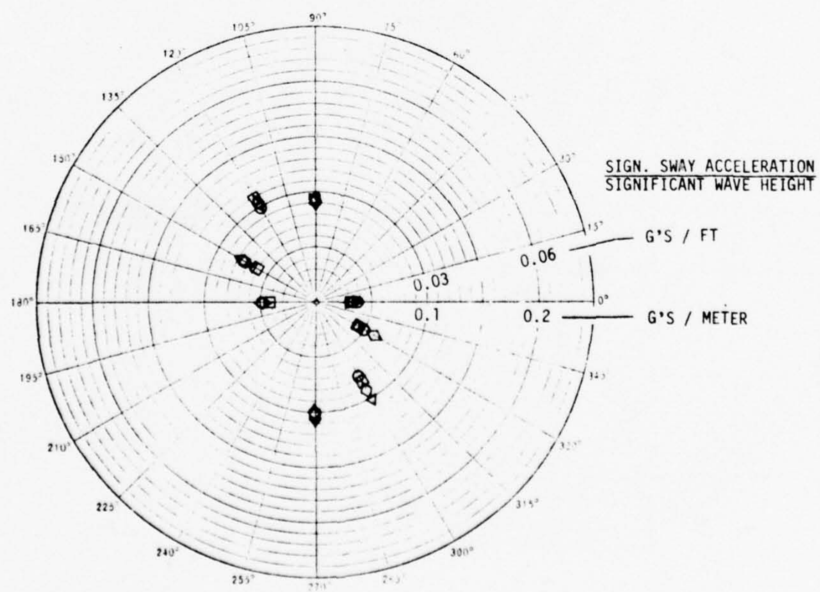


Figure 7b - Significant Double Amplitudes of Sway Acceleration Per Unit Wave Height

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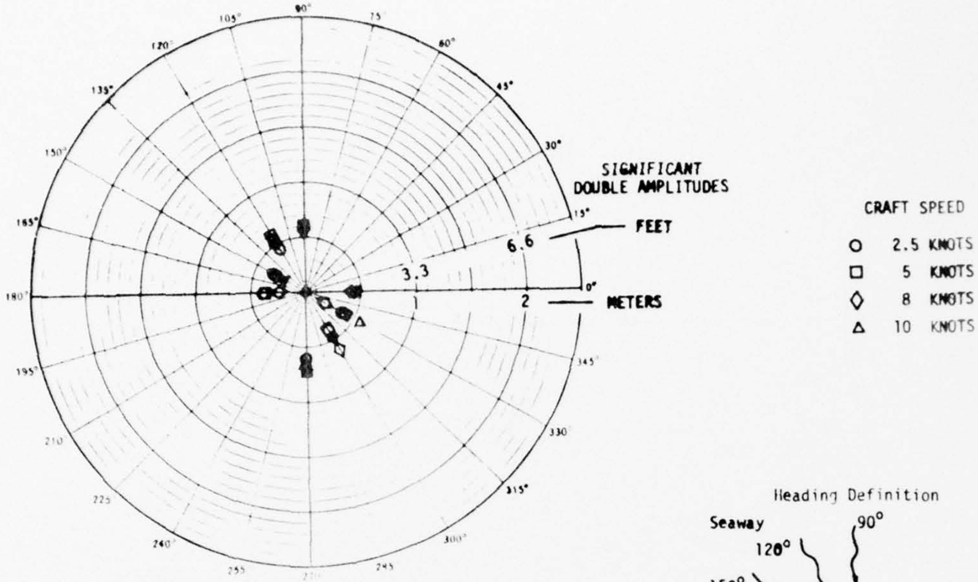
SWAY DISPLACEMENT



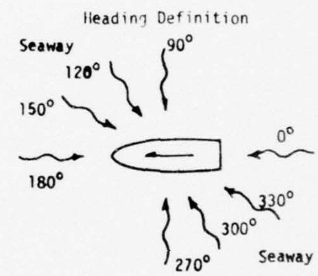


Figure 8a - Significant Double Amplitudes of Sway Motion

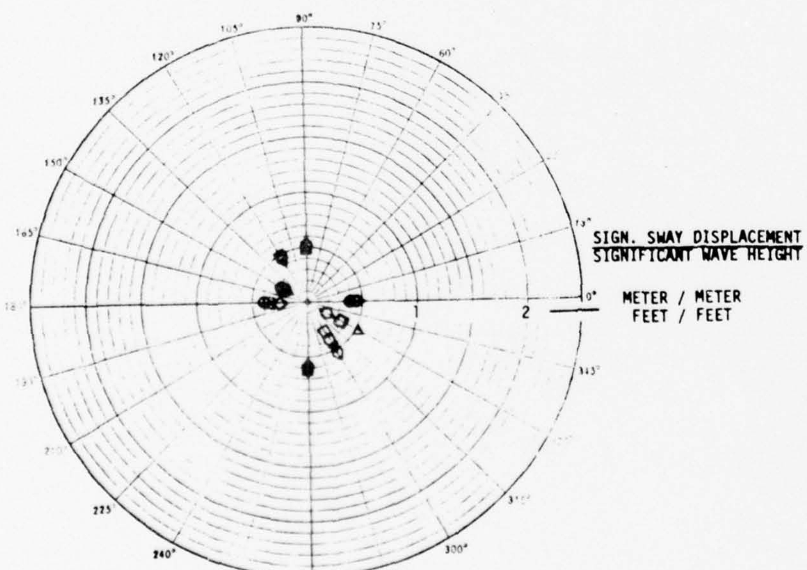
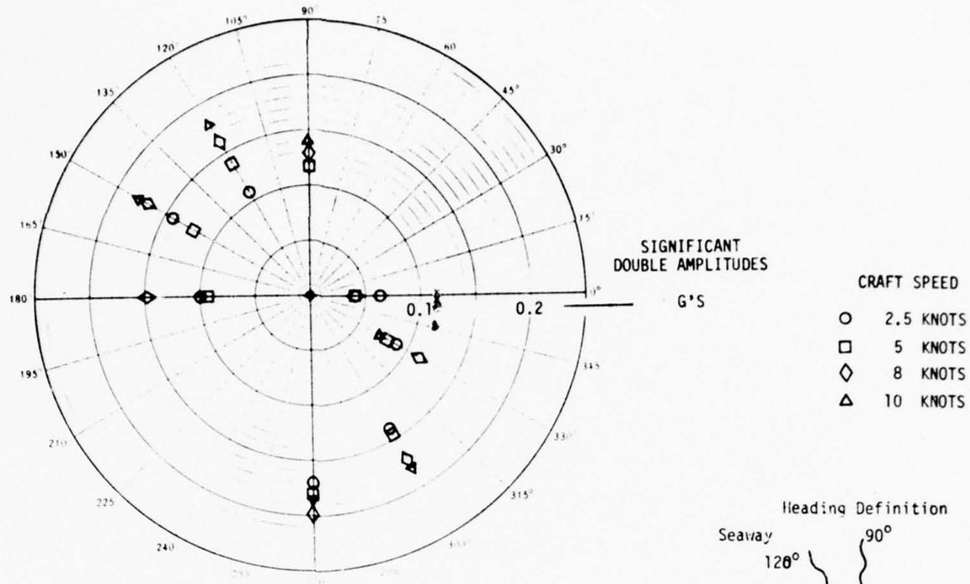


Figure 8b - Significant Double Amplitudes of Sway Motion Per Unit Wave Height

HEAVE ACCELERATION



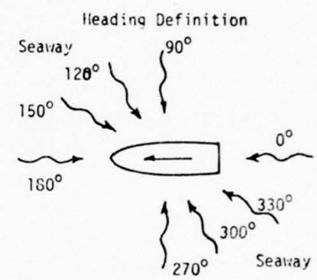


Figure 9a - Significant Double Amplitudes of Heave Acceleration

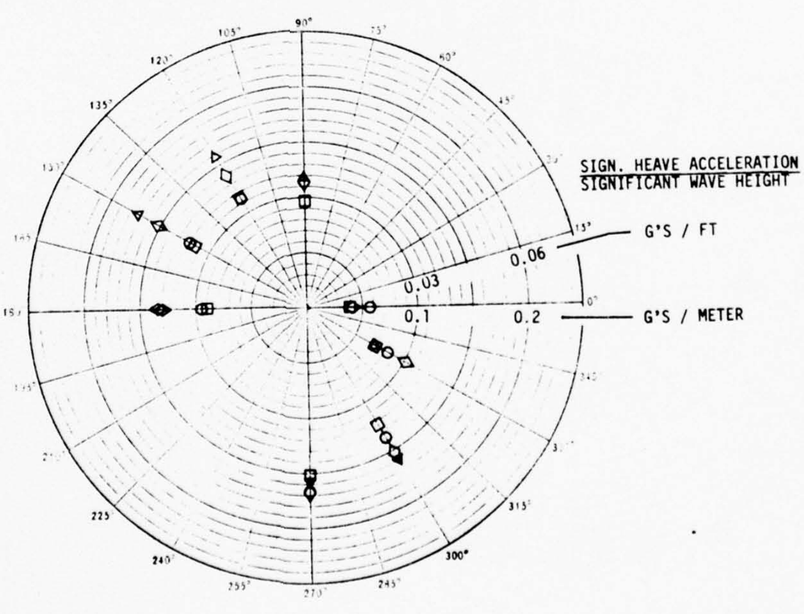


Figure 9b - Significant Double Amplitudes of Heave Acceleration Per Unit Wave Height

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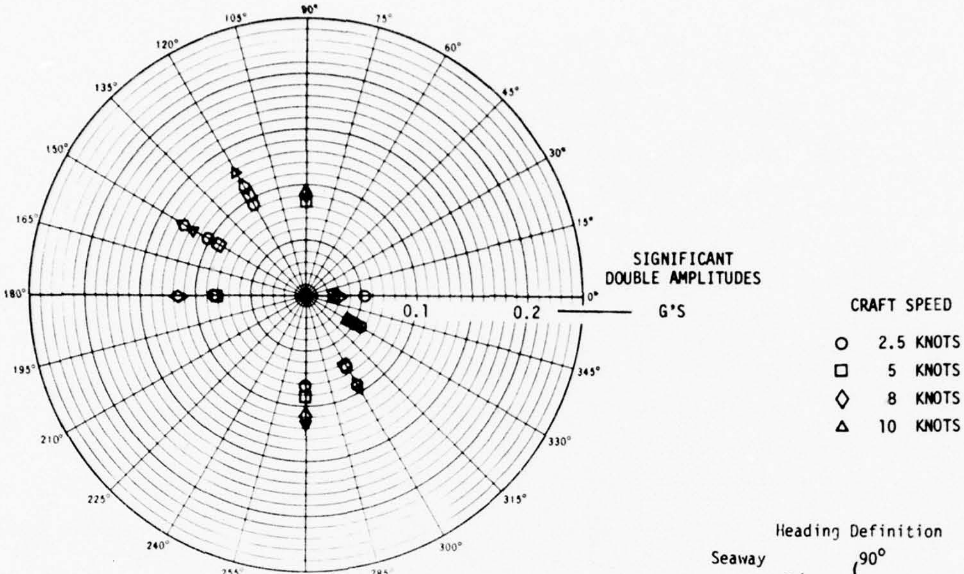
VERTICAL STERN ACCELERATION



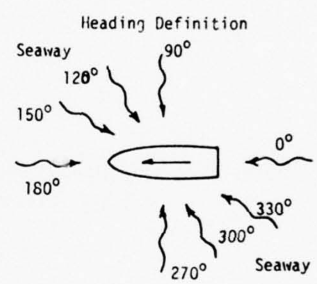


Figure 10a - Significant Double Amplitudes of Vertical Stern Acceleration

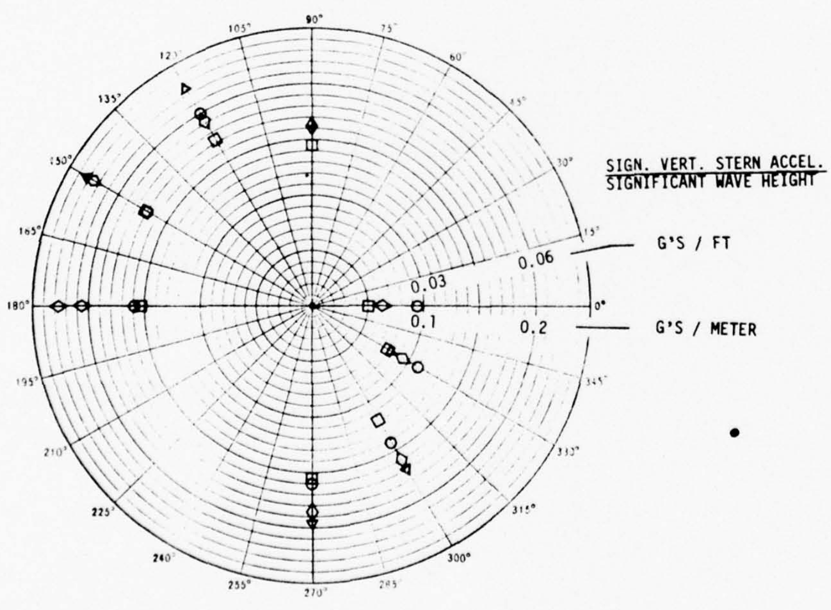


Figure 10b - Significant Double Amplitudes of Vertical Stern Acceleration Per Unit Wave Height

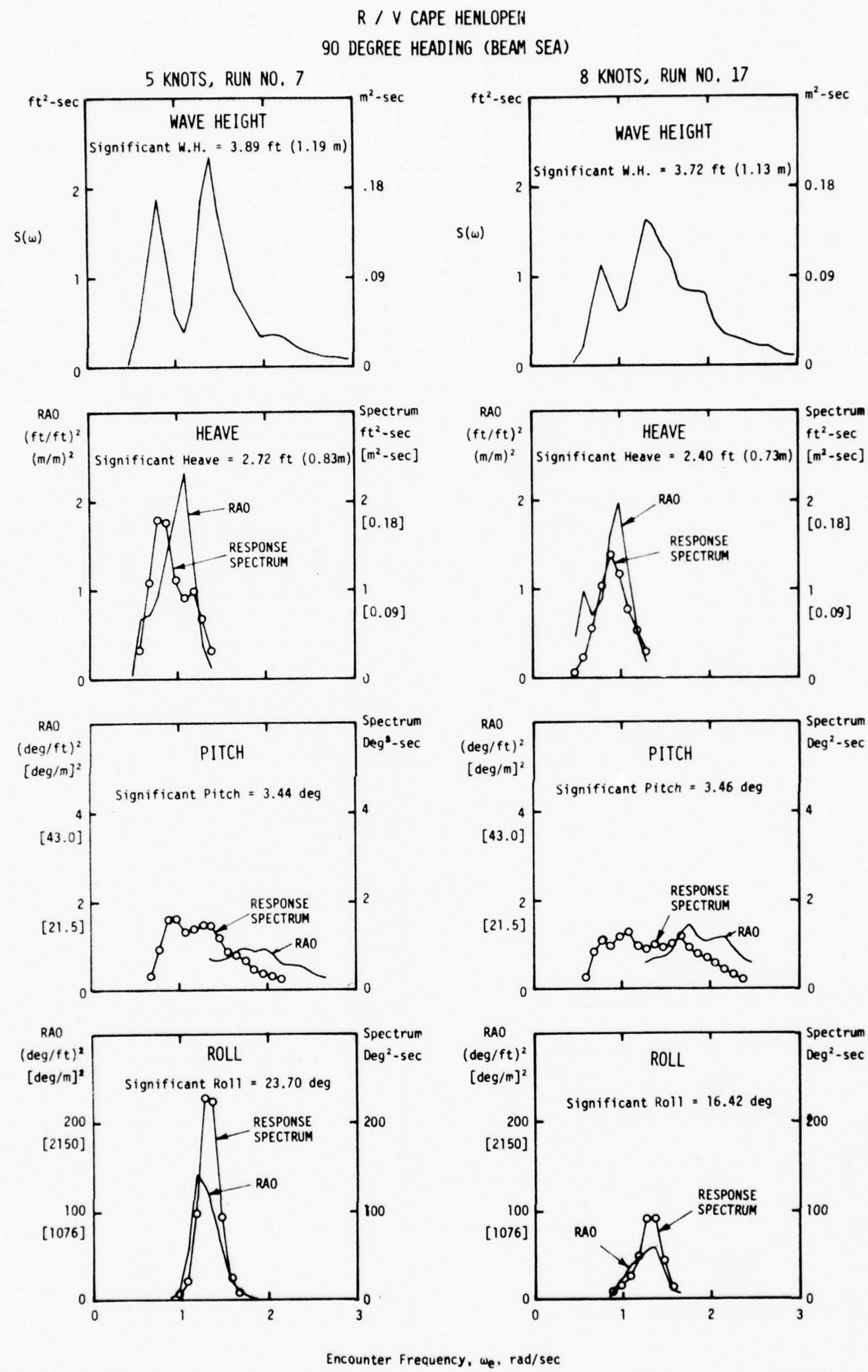


Figure 11 - Motion Spectra and RAO's in Beam Seas (90°) at 5 and 8 Knots

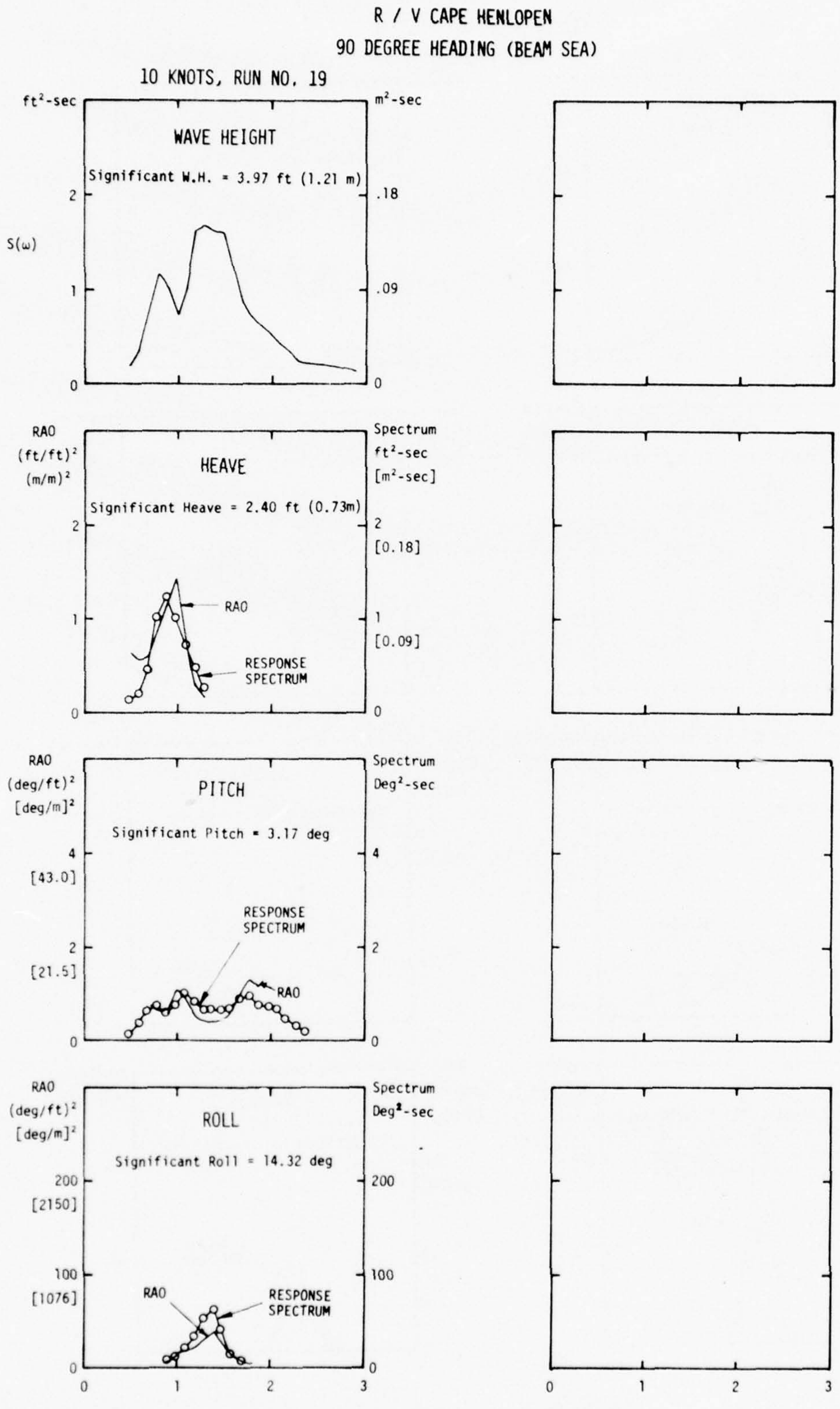


Figure 12 - Motion Spectra and RAO's in Beam Seas (90°) at 10 Knots

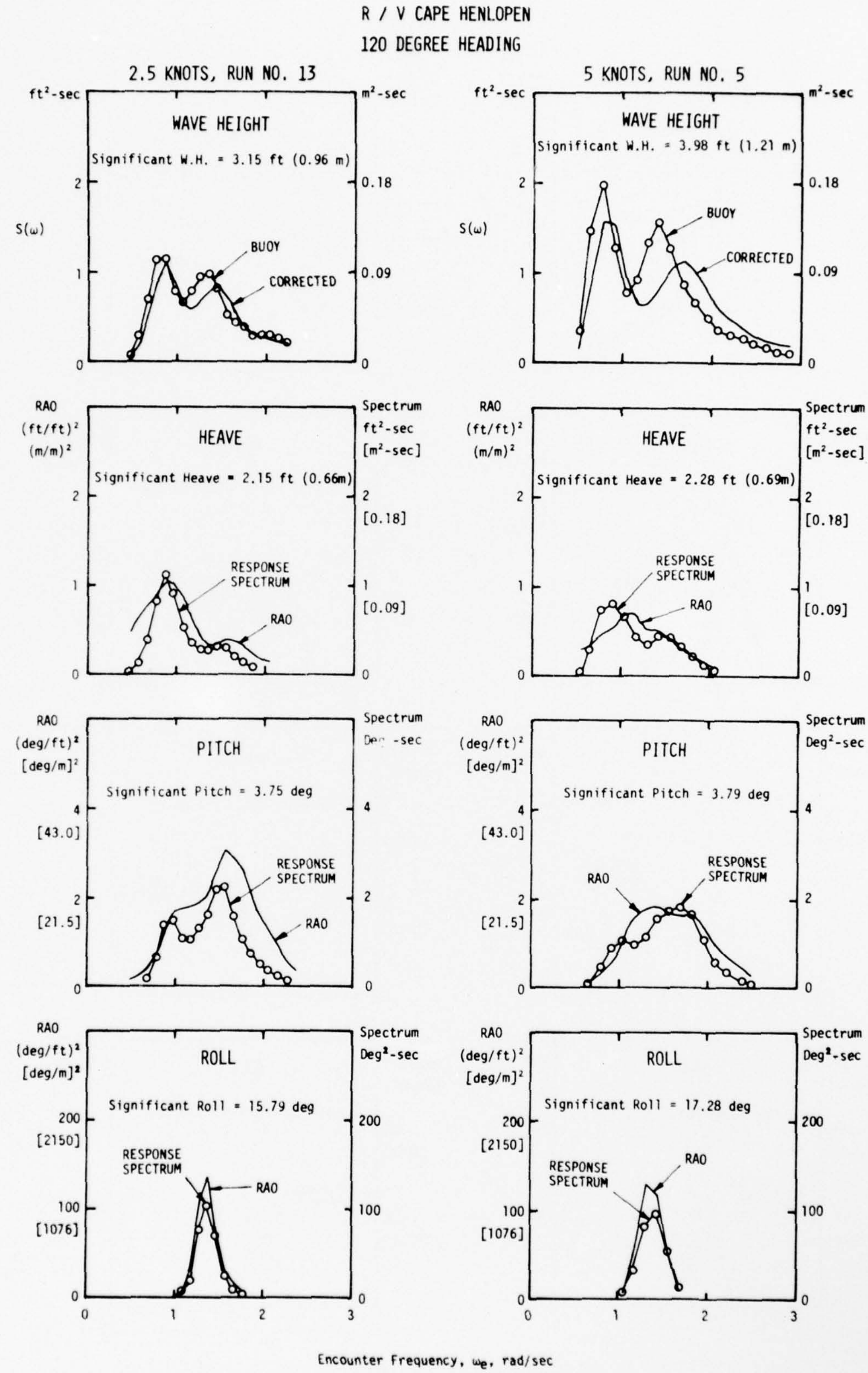


Figure 13 - Motion Spectra and RAO's in Bow Quartering Seas (120°) at 2.5 and 5 Knots

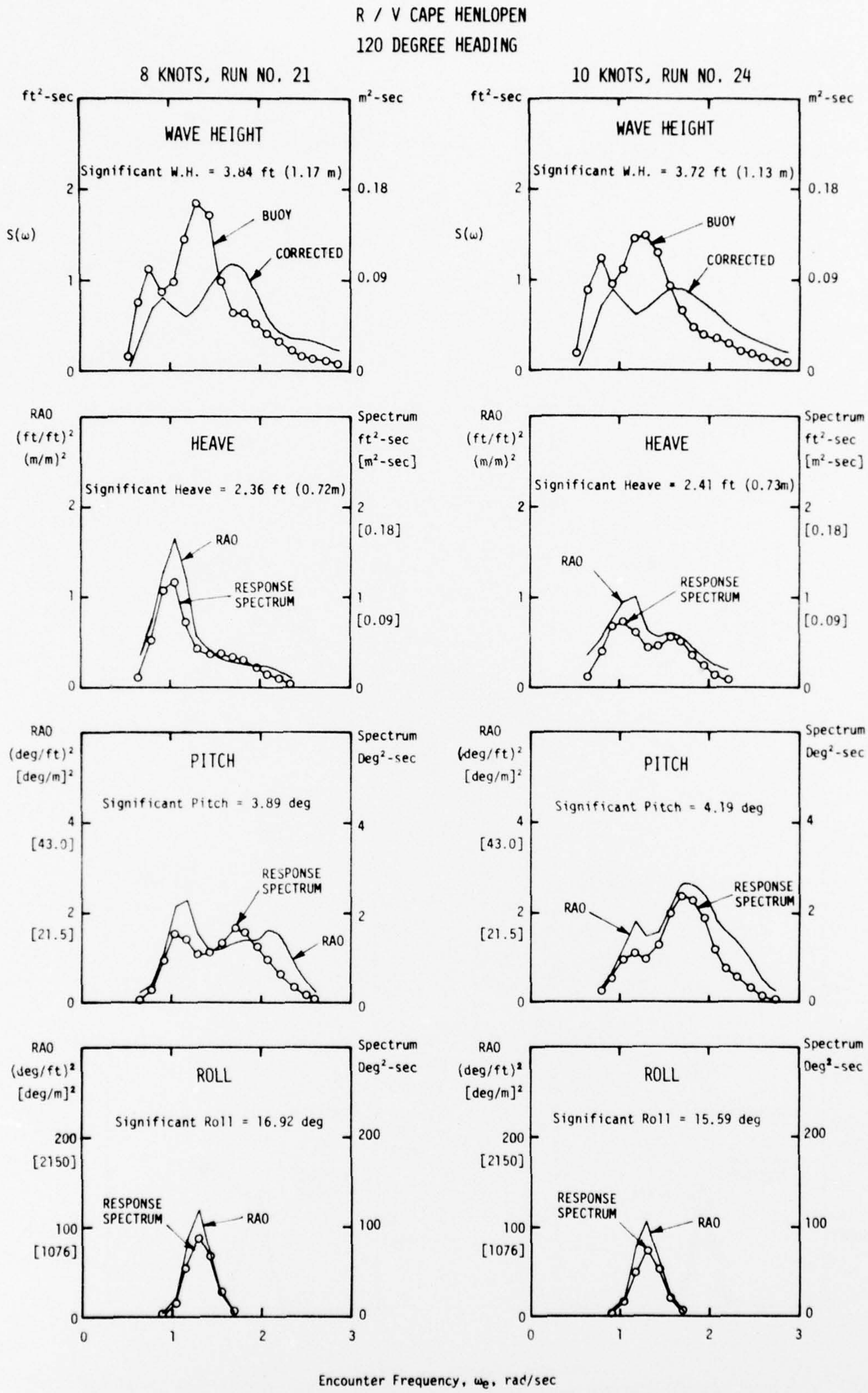


Figure 14 - Motion Spectra and RAO's in Bow Quartering Seas (120°) at 8 and 10 Knots

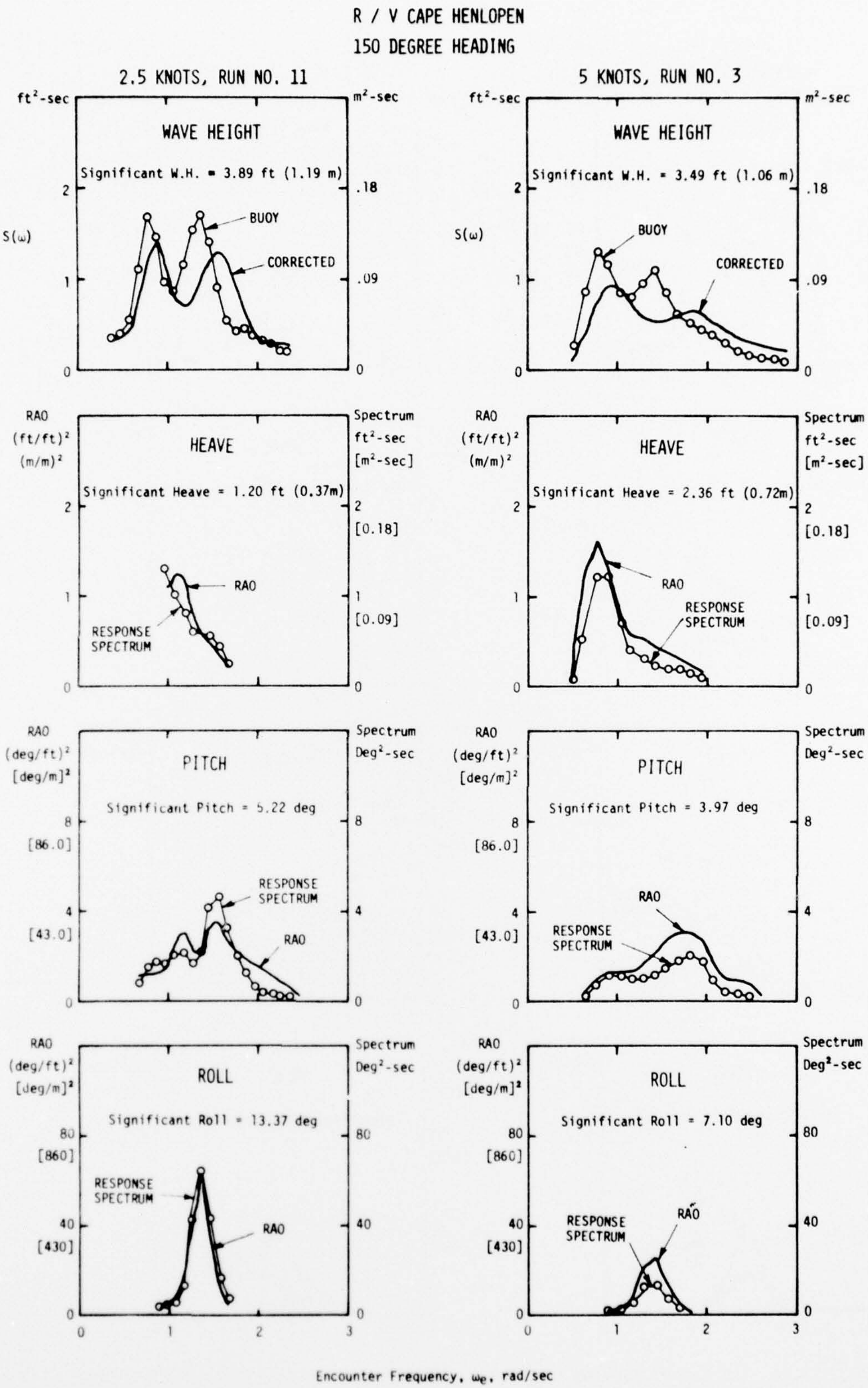


Figure 15 - Motion Spectra and RAO's in Bow Quartering Seas (150°) at 2.5 and 5 Knots

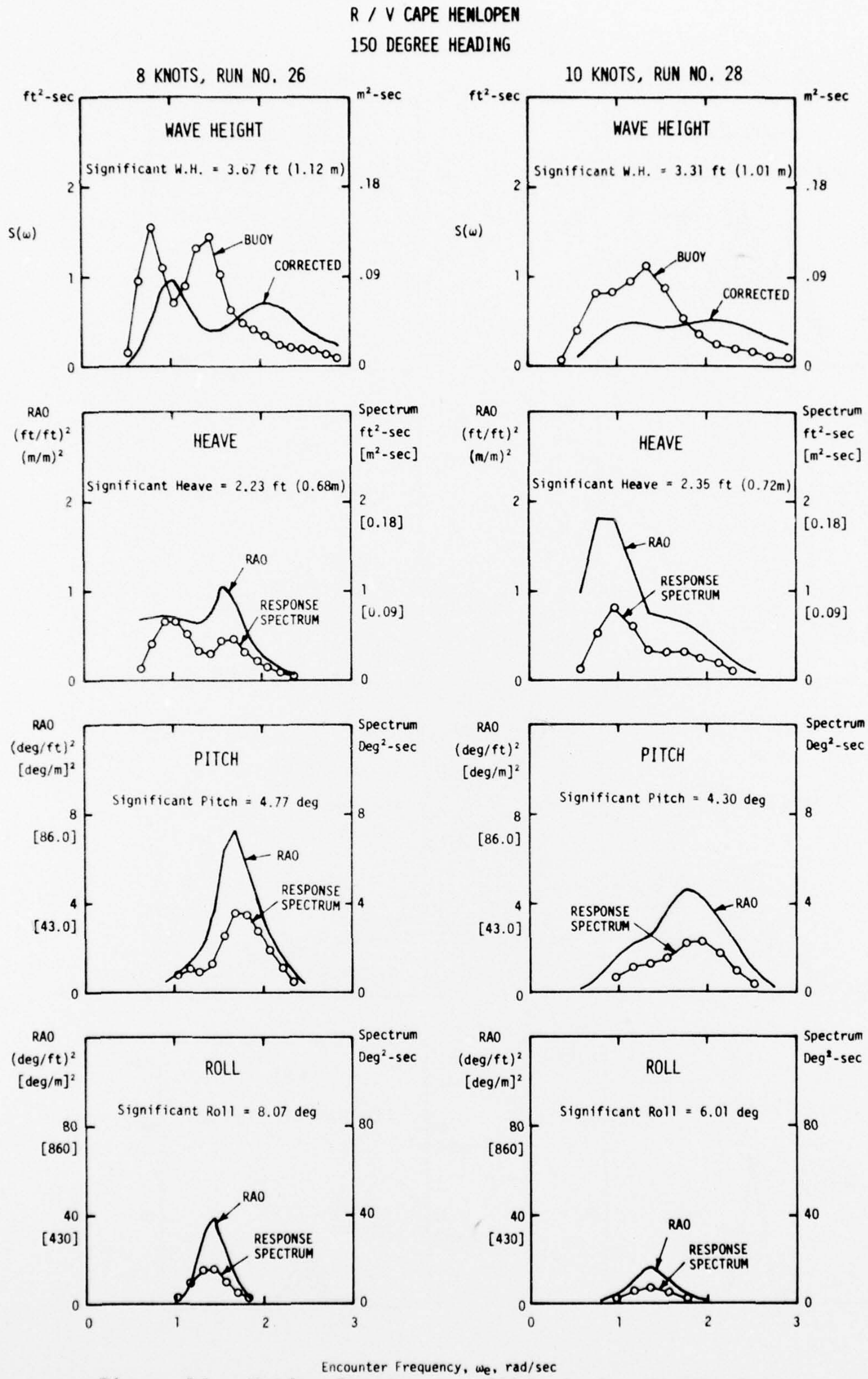


Figure 16 - Motion Spectra and RAO's in Bow Quartering Seas (150°) at 8 and 10 Knots

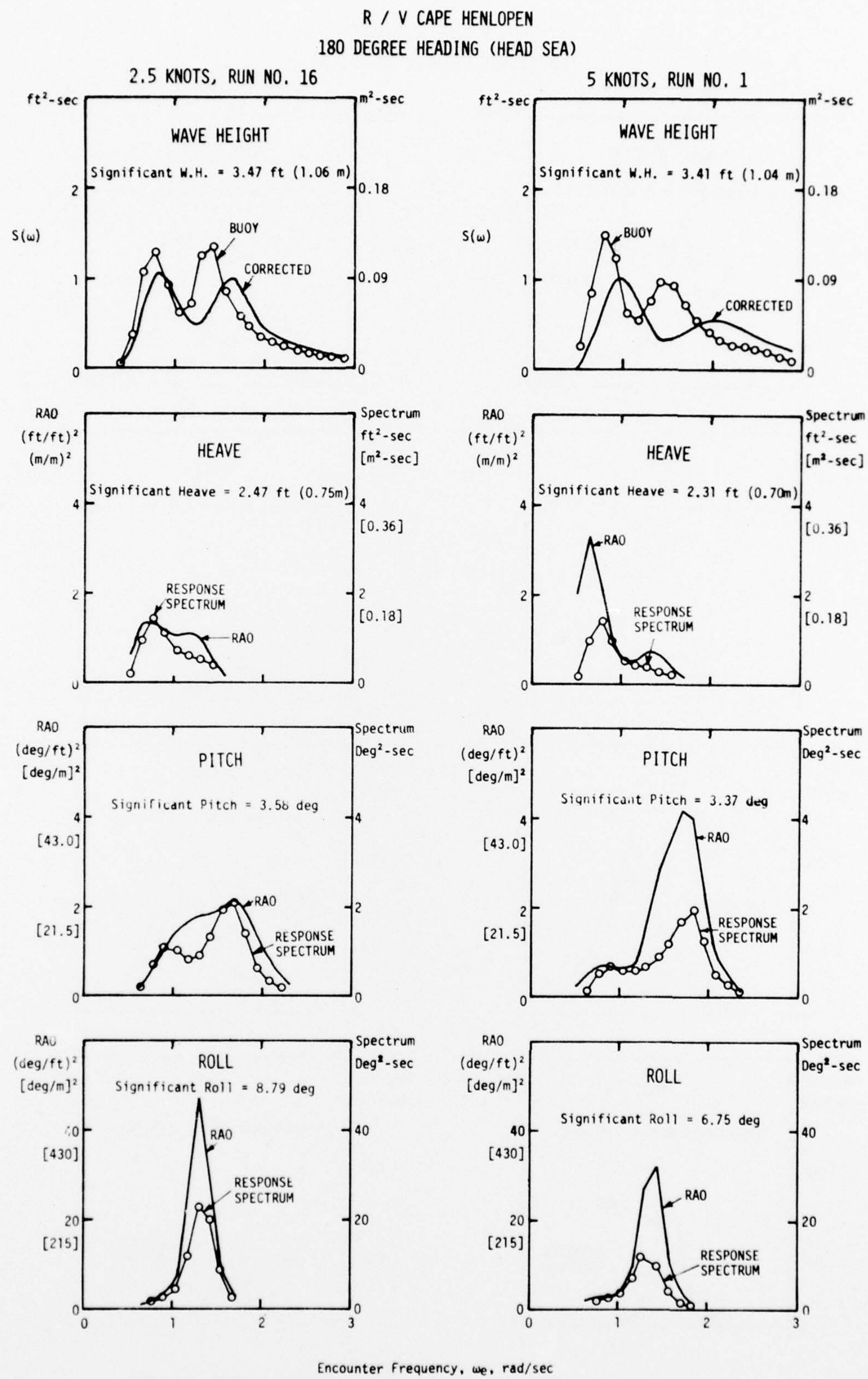


Figure 17 - Motion Spectra and RAO's in Head Seas at 2.5 and 5 Knots

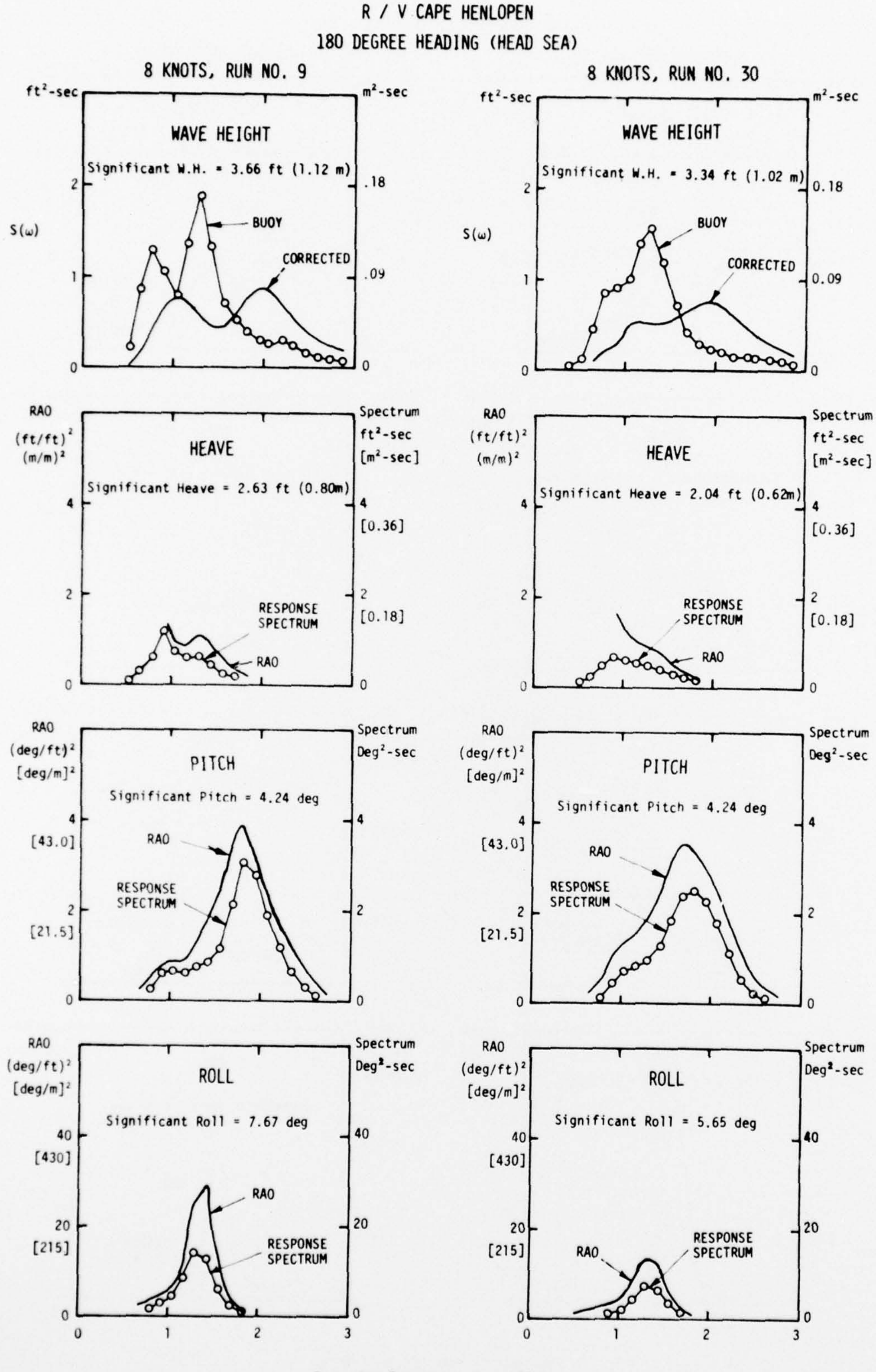


Figure 18 - Motion Spectra and RAO's in Head Seas at 8 Knots

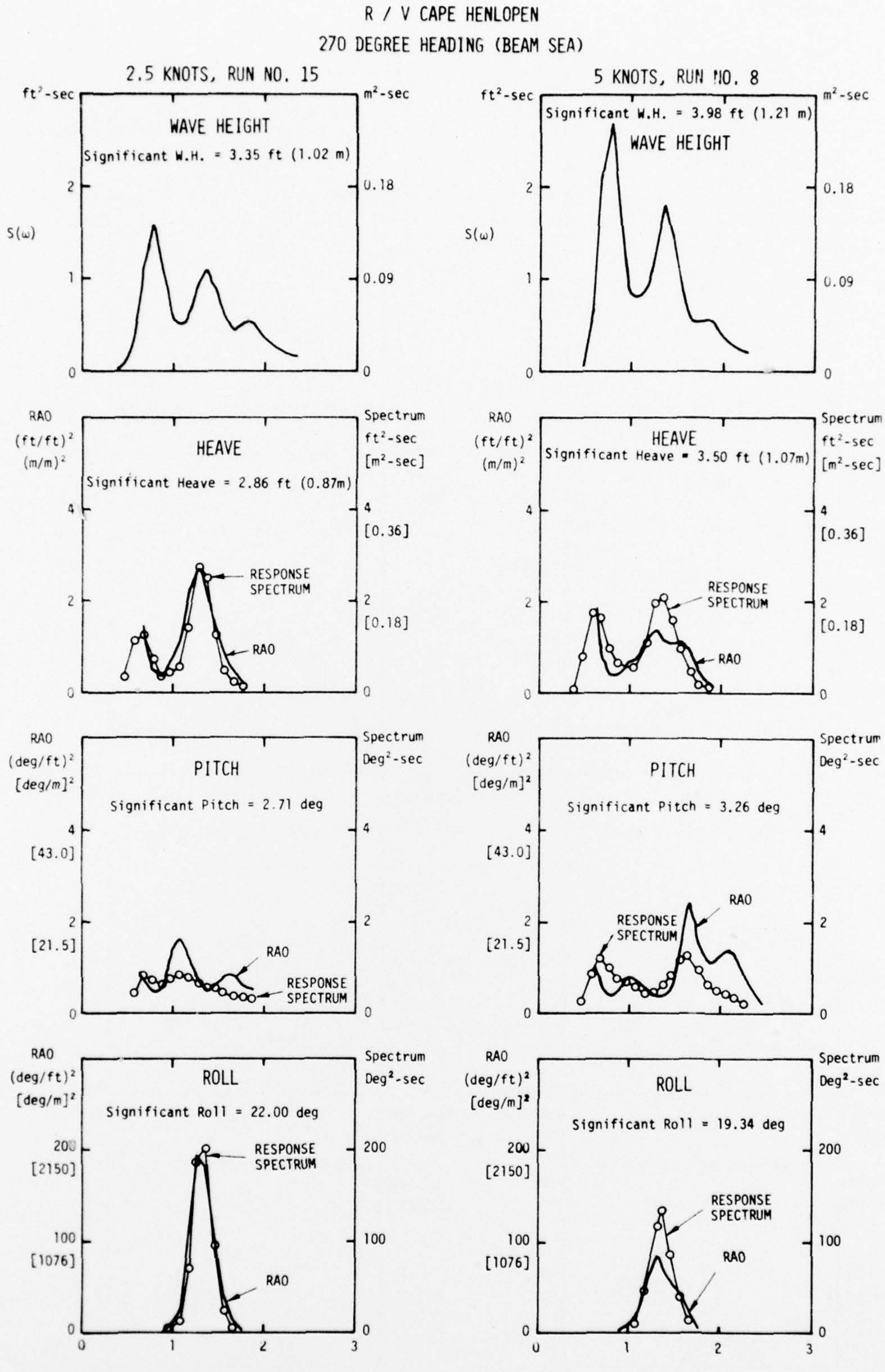


Figure 19 - Motion Spectra and RAO's in Beam Seas (270°) at 2.5 and 5 Knots

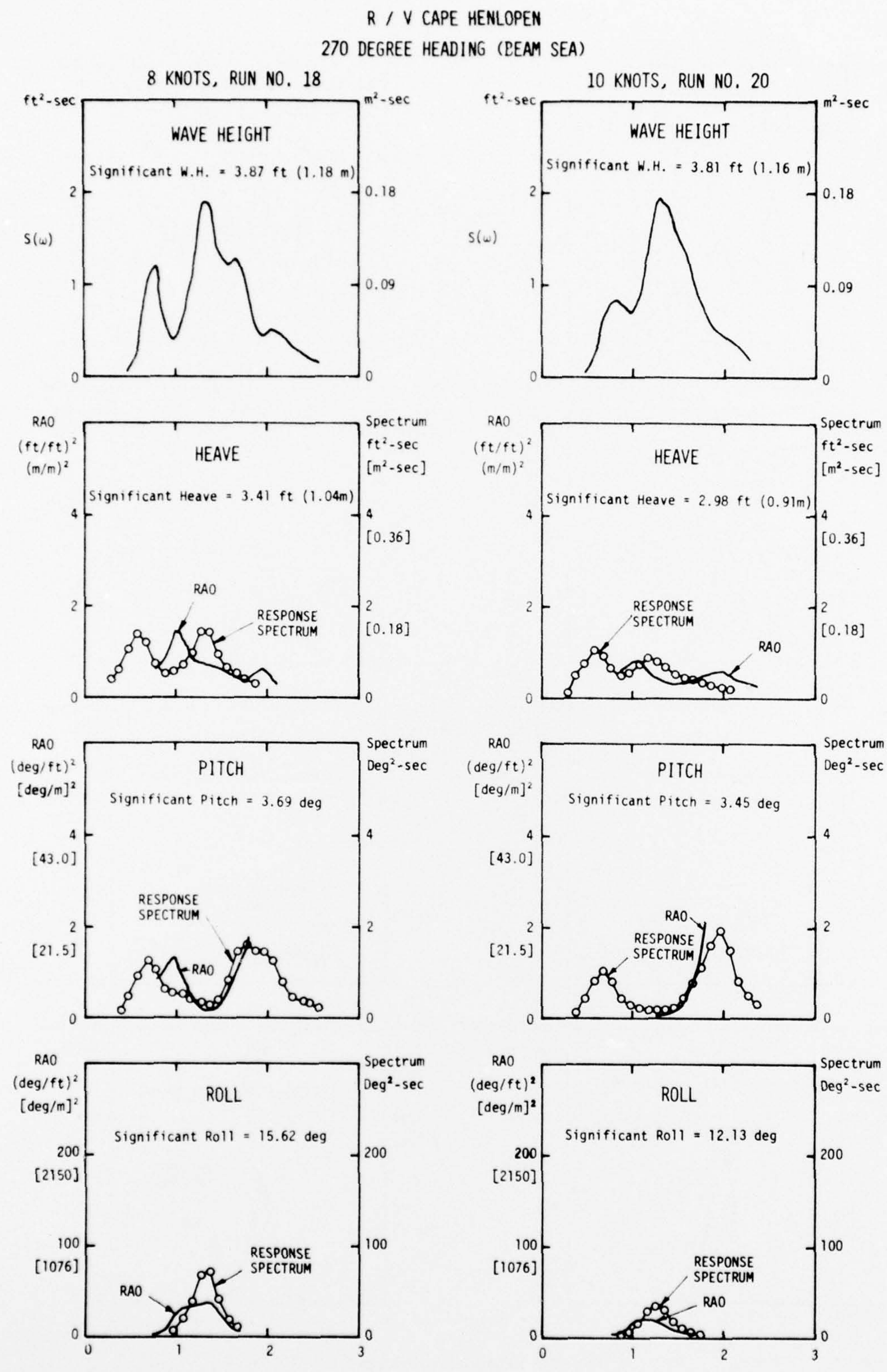


Figure 20 - Motion Spectra and RAO's in Beam Seas (270°) at 8 and 10 Knots

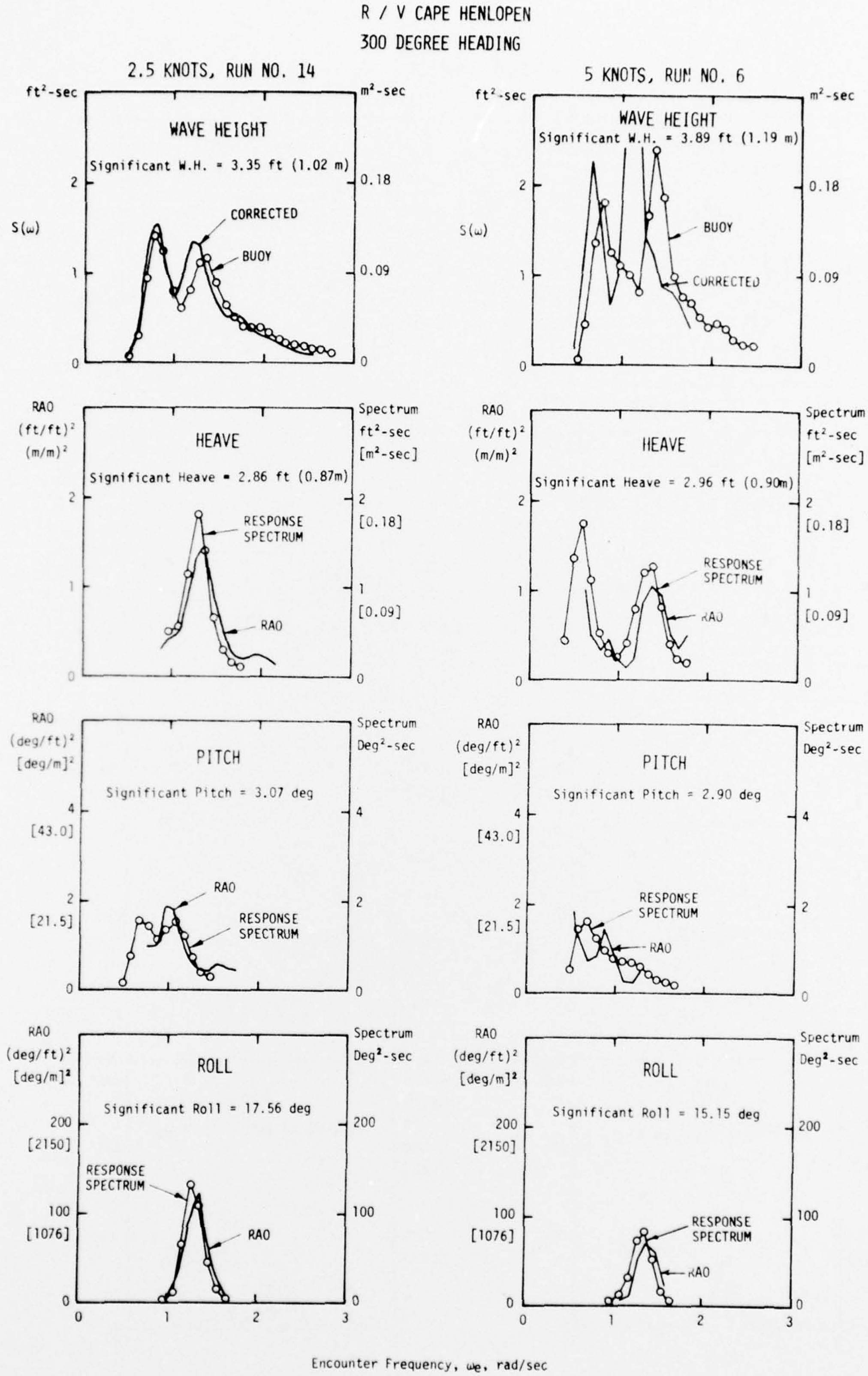


Figure 21 - Motion Spectra in Stern Quartering Seas (300°) at 2.5 and 5 Knots

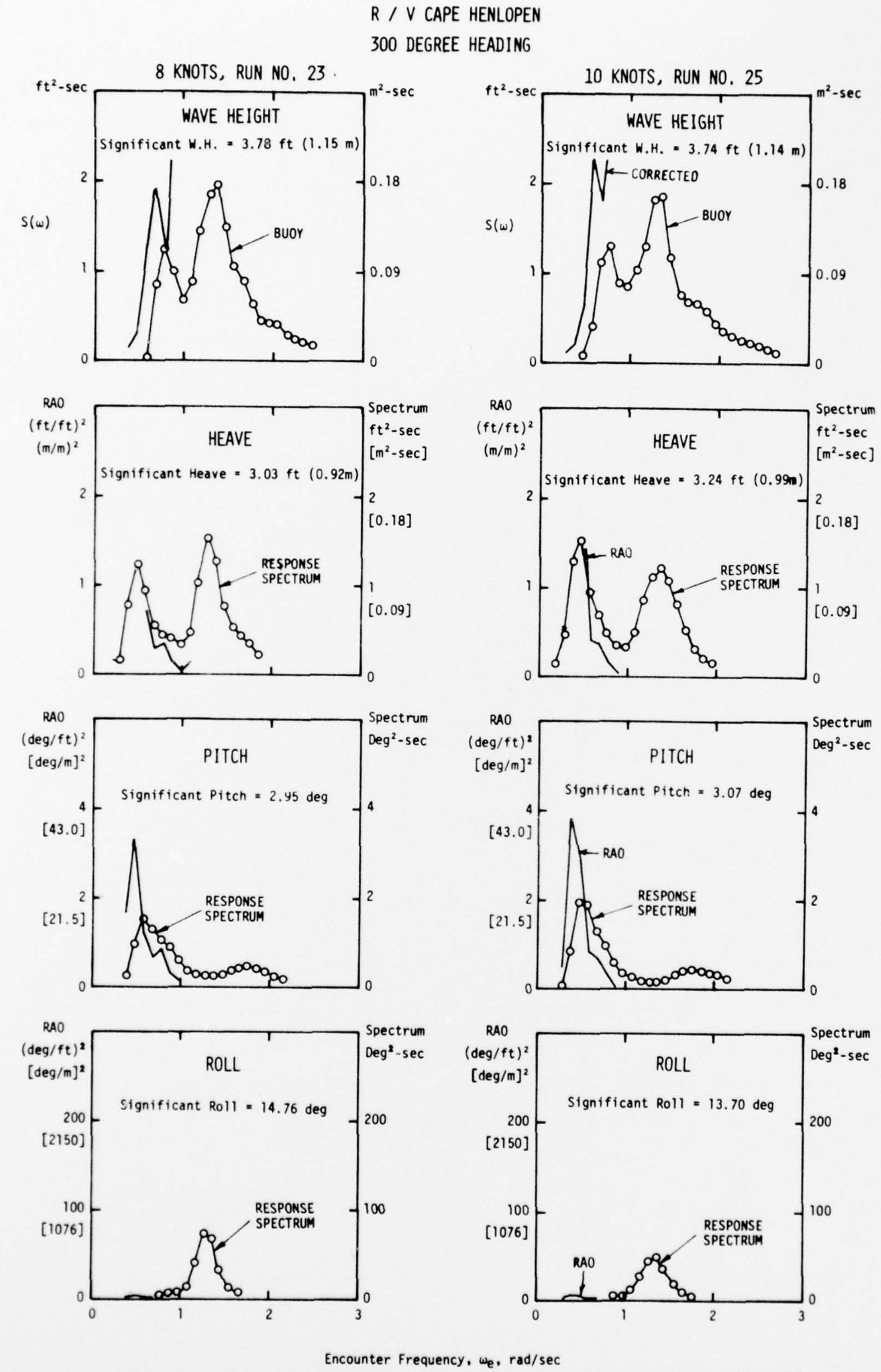


Figure 22 - Motion Spectra in Stern Quartering Seas (300°) at 8 and 10 Knots

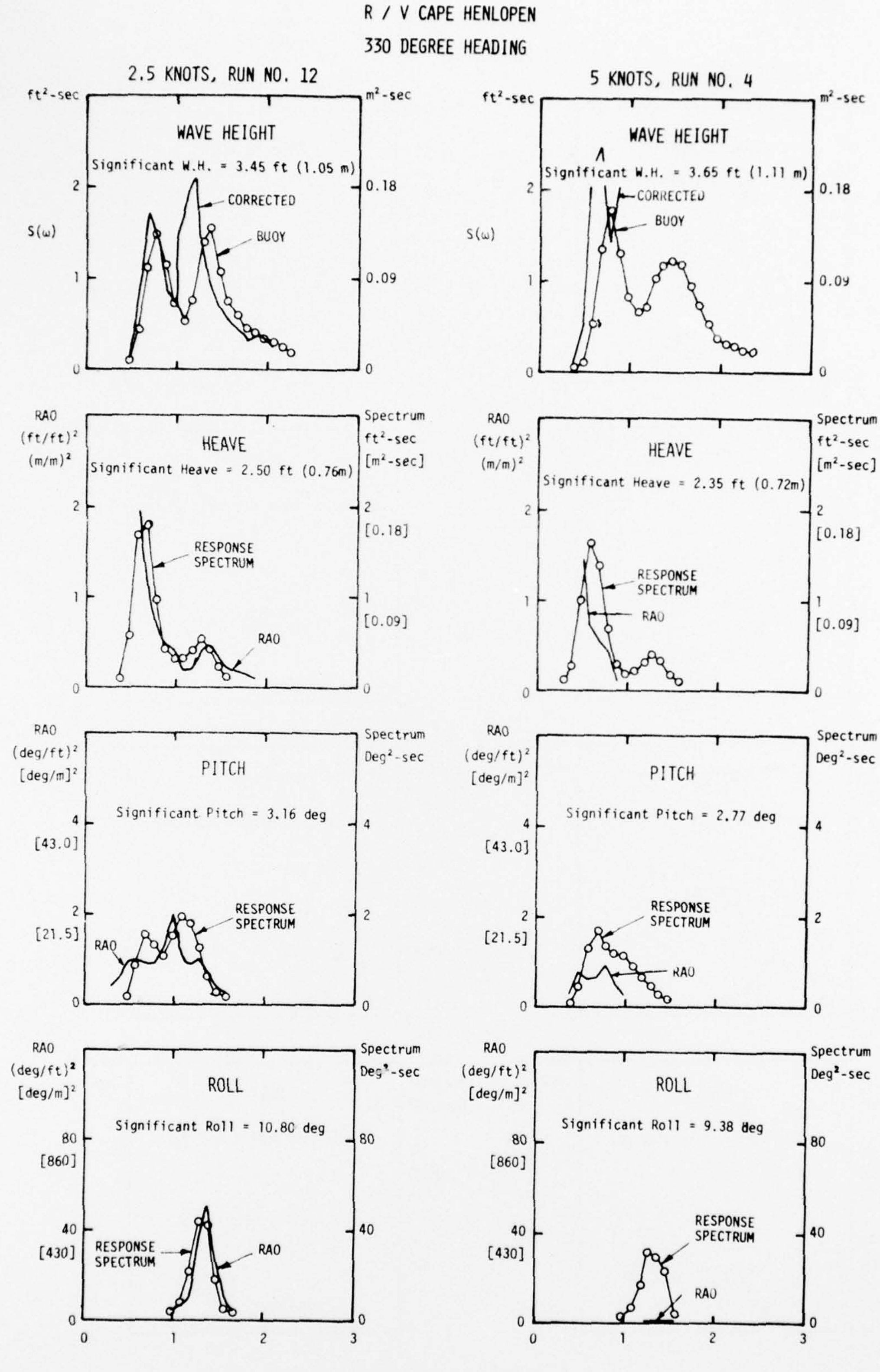


Figure 23 - Motion Spectra in Stern Quartering Seas (330°) at 2.5 and 5 Knots

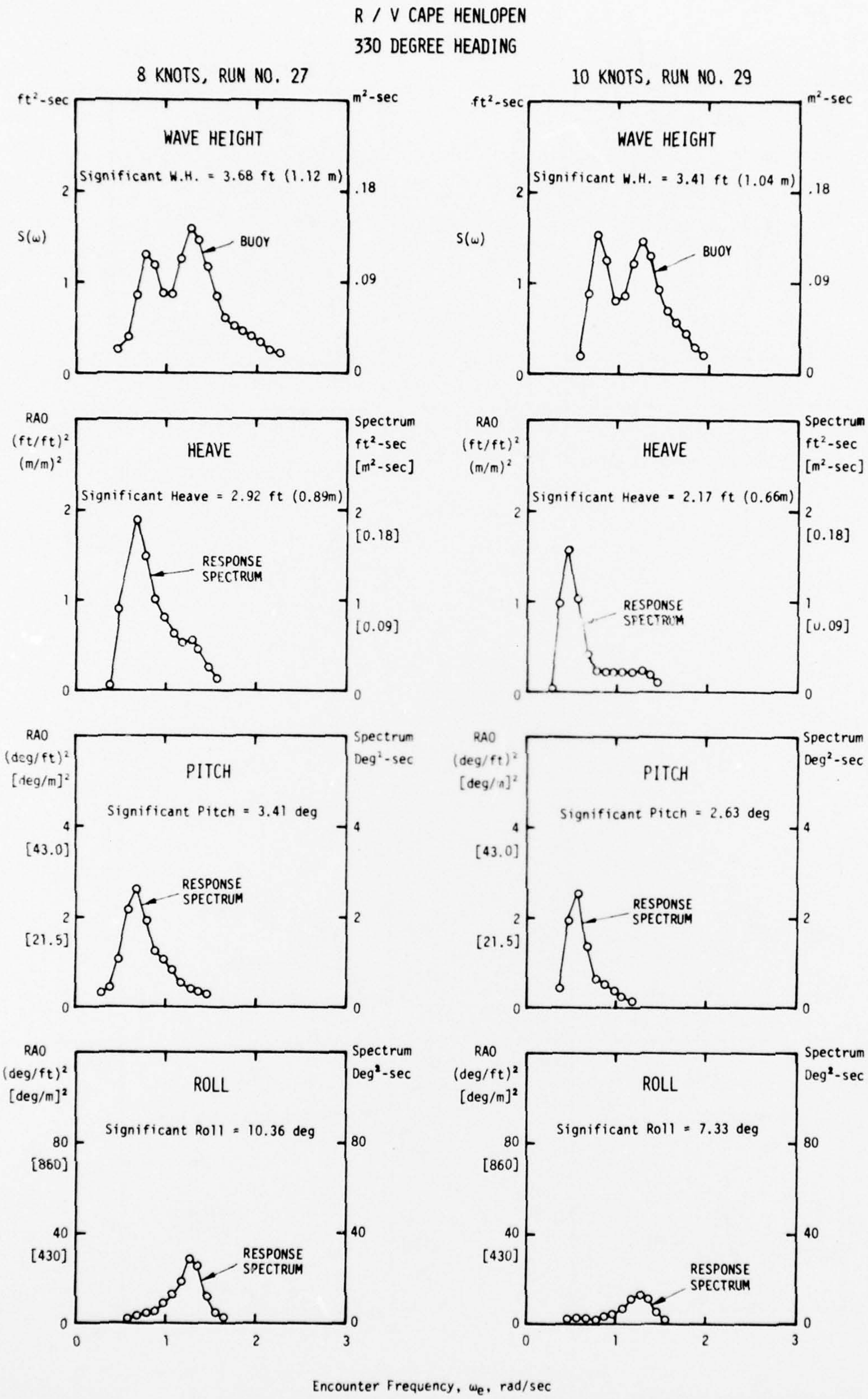


Figure 24 - Motion Spectra in Stern Quartering Seas (330°) at 8 and 10 Knots

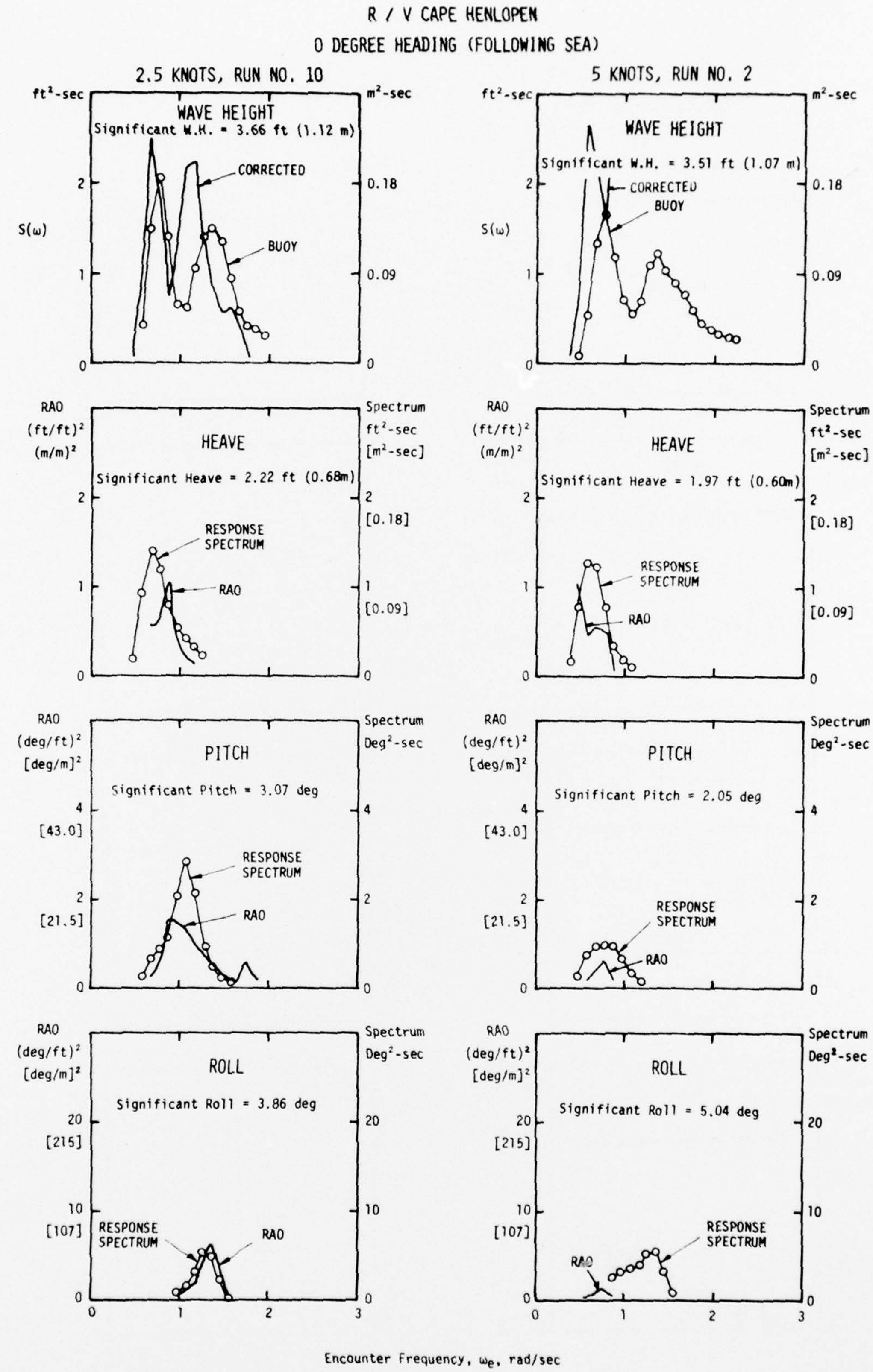


Figure 25 - Motion Spectra in Following Seas (o°) at 2.5 and 5 Knots

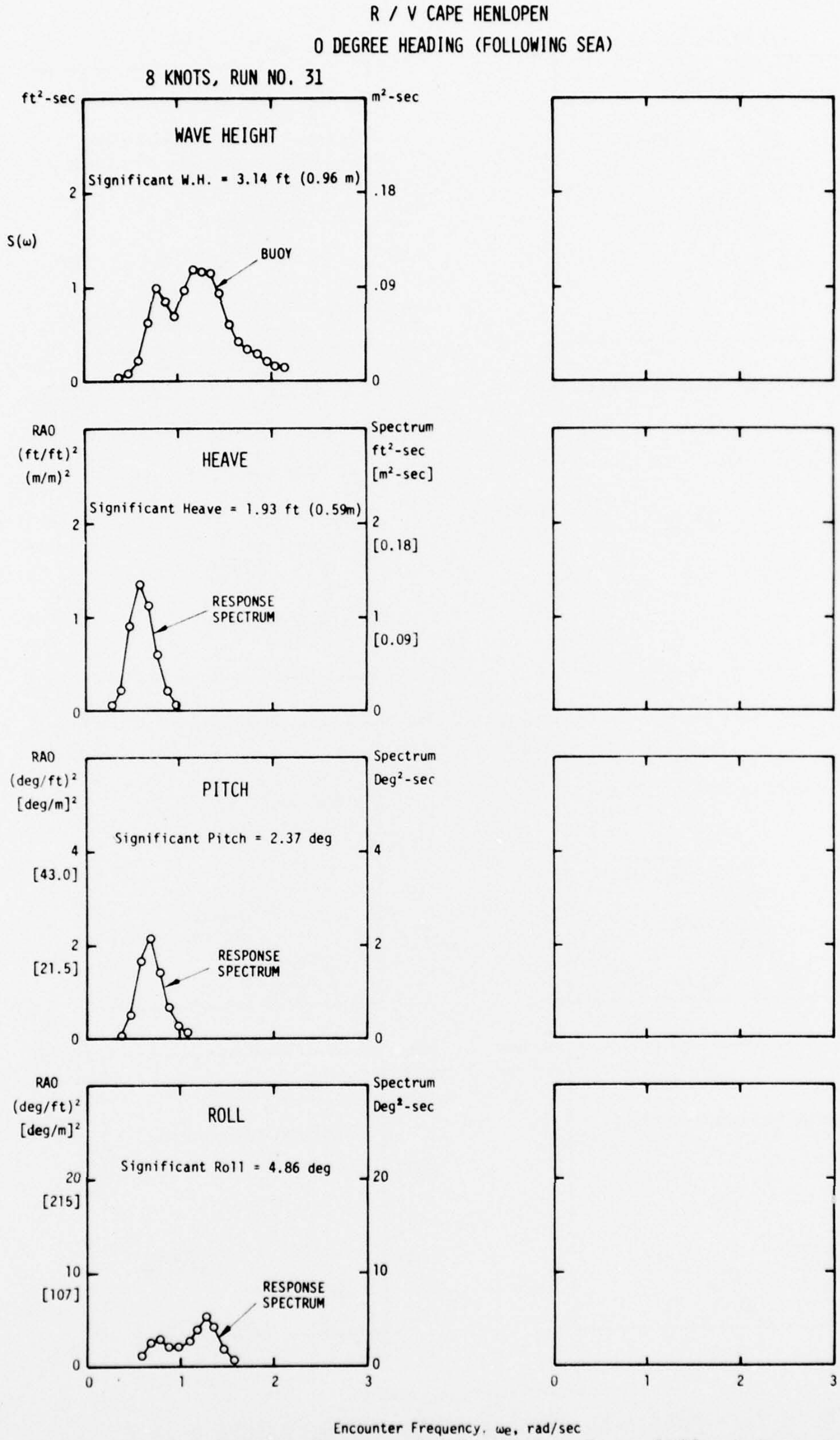


Figure 26 - Motion Spectra in Following Seas (0°) at 8 Knots

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